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EDITORIAL

CURRENT TOPICS: LEGUMINOUS CROPS AND THE FLOODS

RECENT current topics in Ceylon have been leguminous crops and the floods. Arising out of a memorandum published by the Imperial Institute upon the subject our newspapers have been full of the possibility of the establishment of a sunn hemp industry in the Island. *Crotalaria juncea*, the plant from whose stem by a process of retting the sunn hemp is derived, already grows to some extent in the Jaffna Peninsula and its development and possibilities are being closely watched by the Department. The value of this crop in agriculture apart from its economic product is great, for it belongs to the pea and bean family of legumes and like all such plants develops upon its roots the small pill-like nodules which contain bacteria capable of fixing the free nitrogen in the air in the soil and thus enriching the land by an added amount of cheaply obtained fertiliser. It has, therefore, an importance as a soil renovator when its roots and leaves are left behind in a system of crop rotation. Its value would seem especially to be in our lowland plateau districts. Although *Crotalaria juncea* will grow at altitudes of some 2,500 feet, it is not so suited to hillside slopes as other species of *Crotalaria* which are more to be recommended as a green manure crop for upland tea.

With a gust like that of the storm an American periodical presented us with the wisdom of surrounding ourselves with fields of leguminous crops as a method of eradicating malaria. There is supposed to be an element in such crops obnoxious to mosquitoes. The suggestion is not a new one but perhaps not yet beyond the stage of theory. Some have written the Department enquiring about various plants for this purpose that the article mentioned. Alfalfa is the name under which lucerne (*Medicago sativa*) is known and largely grown in North America. It has been tried in Ceylon but not apparently with much success. Where it can be grown it is a most valuable fodder and rotation crop. The possibilities of Bersem or Egyptian Clover (*Trifolium alexandrinum*) sown without cultivation after the first rice crop on land sufficiently moist are worth investigating here by those of an experimental turn of mind who have a care for their cattle.

The storms swelled our rivers to an alarming extent. Their muddy water forcibly reminded us of the wisdom of growing leguminous cover crops and of taking all other means to prevent the best of the upland soil from disappearing into the sea. In connection with this we read with interest the words of Mr. Lushington at the Third British Empire Forestry Conference, the report of which is just to hand: "There is not a river in Ceylon during the rains which contains clear water and the rivers and streams are mostly highways for conveying thousands of tons of the finest soil to the sea. This is not entirely due to shifting cultivation, but largely to the rather pernicious system of weeding rubber and tea estates on the hillsides. The planters have recognised this and are now taking steps to prevent soil erosion on the estates."

The Department hopes soon to publish two publications bearing upon the above topics. One is a manual upon the use of leguminous crops for green manure and cover, and the other the Report of the Soil Erosion Committee.

DRAINAGE AND LEACHING TRIALS AT PERADENIYA, 1927 TO 1930

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IN previous numbers of *The Tropical Agriculturist* (1 and 2) an account has been given of the drainage and leaching trials started at Peradeniya in 1927, and the 1927 and 1928 results have been discussed. The trials were continued in a slightly modified form during 1929. The modification was considered necessary owing to the comparatively large variation observed in the amounts of drainage from the different pots. As nitrogen is, of all the soil fertilising constituents, the one of the greatest importance, it was decided to restrict the scope of the experiment to determining primarily the losses of nitrogen from the soil through leaching. Of the nine pairs of pots, two were treated with each of the three commonly-used nitrogenous fertilisers—nitrate of soda, sulphate of ammonia and cyanamide, and the remaining three were left as controls. The 1929 results can therefore be considered more representative than those of 1927 or 1928. For purposes of comparison the latter are also shown in the tables. The fertilisers were applied on the 10th of January in the same manner as previously. The methods of sampling and analyses of the drainage waters were also the same. It may be here stated that nitrate nitrogen was determined by the phenol disulphonic acid method as modified by Frederick (3), lime, potash and magnesia by the usual analytical methods, ammonia by nesslerisation and phosphoric acid by the Deniges "coerulcomolybdic" methods (4).

THE AMOUNTS OF DRAINAGE AND EVAPORATION

In Tables I, II and III below will be found the amounts of drainage during each month of 1929 from both cropped and uncropped pots, the average drainage figures for 1927 and 1928, and the evaporation and absorption and transpiration data for all three years.

Table I

Treatment in 1929	Previous Treatment	Rainfall (inches) 1929		Drainage (inches) 1929 Uncropped	Cropped
Sulphate of ammonia	Blood meal			48·56	42·99
,, ,,	Sulphate of ammonia			43·81	48·89
			Average	46·18	45·94
Nitrate of soda	Nitrate of soda			47·12	31·36
,, ,,	Nitrate of potash			52·18	37·27
		78·74	Average	49·65	34·31
Cyanamide	Sulphate of potash			45·41	47·64
,,	Cyanamide			45·26	40·99
			Average	45·33	44·31
Control	Superphosphate			51·00	47·21
,,	Muriate of potash			54·36	47·33
,,	Control			49·68	37·51
			Average	51·68	44·01
Total Average		78·74		48·60	42·35

		1928 (inches)	1927 (inches)
Rainfall		89·02	76·60
Average drainage	(Uncropped)	52·43	49·96
Average drainage	(Cropped)	30·15	32·50

Table II

		1927 per cent.	1928 per cent.	1929 per cent.
Average drainage	Uncropped	65·1	58·9	61·7
	Cropped	38·6	33·9	53·8
Average evaporation+absorption	Uncropped	34·9	41·1	38·3
Average evaporation+absorption +transpiration	Cropped	61·4	66·1	46·2
Average transpiration	Cropped	26·5	25·0	7·9

It will be observed from Table I that in the case of the uncropped pots the mean drainage during 1929 is lowest from the cyanamide pots and highest from the controls. Individual pots, however, show fairly large variations, the deviation from the total average being over 20 per cent in one case; but the greatest deviation of the mean of any set of similarly-treated pots from the total average is less than 7 per cent. Of the cropped series, the nitrate of soda pots again show the lowest drainage figures and the sulphate of ammonia pots the highest. The growth of the crop in the former was superior to that in the other pots. The deviations from the general average of the percolation figures of both individual pots and the means of sets of pots are greater in the case of the cropped pots.

From Table II it will be seen that while the average drainage from the uncropped pots in 1929 is much the same as in previous years, the drainage from the cropped pots is considerably higher than previously. Table III will show that this is largely due to the high drainage from the latter in November. The rainfall conditions in 1929 were very unusual, and the droughts of January-March and August-September 1929 affected the crops adversely. Their growth was thus less vigorous and their vitality considerably lower than in previous years. The drainage during November was considerably higher from the cropped pots than from uncropped pots. This may be explained by the fact that the crop had suffered so badly from the drought and the high temperature conditions in the pots, that a large proportion of the roots probably died as a result and later got decomposed. Large spaces were thereby created which facilitated the percolation of the rainfall from these pots. The percentage of evaporation and absorption in 1929 is about the average of the 1927 and 1928 figures. The percentage loss of moisture by transpiration from the cropped pots in 1929, assuming that the losses of moisture from the pots through direct evaporation are the same in the cropped and uncropped pots, works out at about 8 per cent. of the rainfall. This figure is much lower than what it should be; but it was observed that the amount of leaf borne by the crop in 1929 was, as a result of the adverse rainfall conditions, considerably less than that in previous years, hence the low transpiration and the high drainage figures from the cropped pots. As was pointed out when the 1928 results were discussed (2), the high drainage figures obtained are due to the slow drainage of water collected in the pots above the soil which would normally have overflown during periods of heavy rainfall. From 1930 this defect will be overcome by the fixing of outlet pipes to the pots slightly above the surface of the soil. It should thus be possible to obtain in the future more accurate data on percolation from soils under the climatic conditions pertaining at Peradeniya especially as the soil in the pots has now settled down to much more like normal field conditions.

THE RELATION OF DRAINAGE TO RAINFALL

In Table III below are shown the rainfall figures for each month of the year and the corresponding average percolations from the cropped and uncropped pots respectively. A statistical examination of these figures will show that, as previously, there is a positive correlation between the rainfall and drainage from the uncropped pots, but this correlation is lower than previously

probably owing to the uneven rainfall conditions. The correlation is much less definite in the case of cropped pots but there is again a close parallelism between the drainage and rainfall figures. As in previous years, it will be observed that when the rainfall is heavy and continuous the drainage from the cropped pots approximates and in certain instances is even greater, than that from the uncropped pots.

Table III

Month	Rainfall (inches) 1929	Drainage (inches) Uncropped	Drainage (inches) Cropped	Nitrate nitrogen (lb. per acre) Uncropped	Lime (lb. per acre) Uncropped	Lime (lb. per acre) Cropped
January	0·62	nil	nil	nil	nil	nil
February	0·67	nil	nil	nil	nil	nil
March	5·86	1·07	nil	9·5	11·1	nil
April	15·82	11·51	9·14	86·5	105·0	15·8
May	3·66	1·80	0·33	20·8	18·9	0·8
June	9·54	8·39	5·88	63·8	71·6	7·0
July	7·29	5·21	5·77	29·1	38·9	7·3
August	0·58	nil	nil	nil	nil	nil
September	7·18	3·69	3·12	19·9	31·2	3·7
October	4·11	1·57	nil	13·6	15·9	nil
November	19·15	13·94	18·11	75·7	114·9	19·3
December	4·26	1·42	nil	8·7	12·5	nil

THE COMPOSITION OF THE DRAINAGE WATERS

During 1929 analyses of the drainage waters were made for total solids, nitrate nitrogen, and lime. The summarised results are shown in Table IV below, and Table III shows the average amounts of fertilising constituents lost in the drainage waters from the pots each month.

Table IV

p.p.m. = average parts per million; U = uncropped; C = cropped.

Total Solids

Treatment		Lb. per acre 1929	Lb. per acre 1928	Lb. per acre 1927	p.p.m. 1929	p.p.m. 1928	p.p.m. 1927
Control	(U)	2776	3139	3906	247	261	323
,,	(C)	462	458	1854	54·4	71	280
,,	(U)	2624			227		
,,	(C)	612			57·2		
,,	(U)	3012			245		
,,	(C)	581			54·2		
Average Control	(U)	2800			240		
,, ,,	(C)	552			55·3		

Nitrate Nitrogen

Treatment		Lb. per acre 1929	1928	1927	p.p.m. 1929	1928	1927
Nitrate of soda	(U)	322·4	521	482	30·2	45·4	44·1
" " "	(C)	2·7			0·4		
" " "	(U)	346·8			29·2		
" " "	(C)	5·4			0·6		
Average Nitrate of Soda	(U)	334·6			29·7		
" " "	(C)	4·1			0·5		
Sulphate of ammonia	(U)	314·8	479	509	31·7	41·4	46·1
" "	(C)	1·7			0·2		
" "	(U)	348·6			31·7		
" "	(C)	8·3			0·9		
Average Sulphate of ammonia	(U)	331·7			31·7		
" " "	(C)	5·0			0·5		
Cyanamide	(U)	322·7	490	547	31·5	43·5	48·8
"	(C)	0·9			0·1		
"	(U)	306·2			29·3		
"	(C)	0·5			0·05		
Average Cyanamide	(U)	314·5			30·4		
" "	(C)	0·7			0·1		
Control	(U)	380·0	520	510	33·7	43·2	47·0
"	(C)	4·1			0·5		
"	(U)	299·3			25·9		
"	(C)	1·4			0·1		
"	(U)	323·1			26·2		
"	(C)	1·0			0·1		
Average Control	(U)	334·1			28·3		
" "	(C)	2·2			0·2		
General Average	(U)	329·3	502	511	29·9	42·9	45·8
" "	(C)	2·9	12	156	0·3	1·9	23·3

Lime

Treatment		Lb. per acre 1929	1928	1927	p.p.m. 1929	1928	1927
Sulphate of ammonia	(U)	387·9	474	553	39·1	41·0	50·0
" "	(C)	63·3	40	204	5·7	5·2	29·1
" "	(U)	422·3			38·4		
" "	(C)	53·3			5·5		
Average Sulphate of ammonia	(U)	405·0			38·8		
" " "	(C)	58·6			5·6		
Control	(U)	440·0	480	589	39·1	39·9	54·3
"	(C)	47·9	42	275	5·6	6·5	41·6
"	(U)	451·9			36·7		
"	(C)	60·8			5·7		
"	(U)	398·6			34·5		
"	(C)	61·4			5·7		
Average Control	(U)	430·1			36·7		
" "	(C)	57·0			5·7		
General average	(U)	420·0	484·2	590·4	37·6	39·8	52·5
" "	(C)	57·6	43·4	224·6	5·7	6·0	33·5

It will be seen from the tables that there is a close parallelism between the amounts of rainfall and drainage and the amounts of nitrate nitrogen and lime in the latter in the case of uncropped pots. The average concentrations (p.p.m.) of nitrate nitrogen and lime from the uncropped pots though treated differently do not vary much. The maximum percentage difference of the mean of a set of pots treated alike from the total mean is not more than 6 in the case of the nitrate nitrogen concentrations, and 5 in the case of the lime concentrations of the drainage waters from the uncropped pots. The fact, that the variation in the concentrations of the drainage waters from the uncropped pots differently treated is small is apparent from the 1927 and 1928 results as well. This is particularly noted in the case of the nitrogen and lime pots. As the concentrations of potash in the drainage waters are much smaller, the variations between the different pots work out relatively higher if percentages are reckoned. The average concentrations of nitrate nitrogen and lime in the drainage waters have however fallen appreciably during the years 1927 to 1929. Thus in the case of nitrate nitrogen, the average concentration in 1929 is 29·9 p.p.m. as against 42·9 in 1928 and 45·8 in 1927; with lime it is 37·6 in 1929, 39·8 in 1928 and 52·5 in 1927. The observations made apply in the case of the cropped pots as well, but to a lesser degree. The total amounts of fertilising constituents lost in the drainage waters are much less in 1929 than in 1928 or 1927, especially in the case of uncropped pots, although the total drainage is about the same during each of these years. This is especially so in the case of nitrate nitrogen.

Table V

Average Ratios (Uncropped/Cropped)

Treatment	1929	1928	1927
Total solids	5·1	6·8	2·1
Nitrate nitrogen	114·0	41·2	3·4
Lime	7·3	11·2	2·7

In Table V above are shown the average ratios between the amounts of fertilising constituents lost from the cropped and uncropped pots from 1927 to 1929. In the case of nitrate nitrogen, the losses during 1929 from the cropped pots are extremely small, these having become progressively lesser each year. The uncropped nitrate pots had lost 3·4 times more nitrate nitrogen than the cropped pots in 1927, 41·2 times in 1928 and 114 times in 1929. In the case of lime, the ratios do not show anything like the same differences. The 1928 results

therefore confirm what has been found previously viz., that notwithstanding a heavy rainfall, the losses of fertilising constituents particularly of nitrate nitrogen in the drainage waters from soil can be greatly reduced by the presence of a good cover crop.

In the following paragraphs, the total solid, nitrate nitrogen and lime results are examined in greater detail.

Total Solids.—The 1929 results indicate that the average total losses of total solids are less than those of 1928 or 1927 in the case of the uncropped pots, but owing to the greater drainage, slightly higher than the 1928 losses in the case of the cropped pots. The average concentrations of these constituents in the drainage waters are however less in 1929 than in 1928 or 1927.

Nitrate Nitrogen.—(1) Nitrates are found in the drainage waters from both uncropped and cropped pots in much lower concentrations and quantities in 1929 than in previous years. The losses from the cropped pots are almost nil. (2) The losses from the uncropped pots of nitrogen added in the form of fertilisers are still small when compared with the soil nitrogen losses. The differences between the average losses from sets of cropped pots treated differently are not appreciable and cannot be considered significant. (3) Of the uncropped pots, the lowest average losses during 1929 are from the cyanamide pots and the greatest from the nitrate of soda pots. The losses are directly dependent on the drainage, the drainage being greatest from the nitrate of soda pots and lowest from the cyanamide pots. (4) The deviation from the general mean of the nitrate nitrogen concentrations of the drainage waters from individual uncropped pots or sets of pots is not greater than 7 per cent. The deviations are greater in the case of the cropped pots.

Lime.—(1) The amounts of lime found in the drainage waters continue to be high, but are lower than those found in 1928. (2) Owing to the higher drainage from the uncropped control pots and the inclusion of the former muriate of potash pot which had previously shown highest losses of lime, these show, on the average, larger losses of lime through leaching than the sulphate of ammonia uncropped pots. (3) The average amount of lime lost from the cropped pots is however very slightly greater from the sulphate of ammonia pot than from the control, but the difference cannot be regarded as significant. (4) The lime concentrations in the drainage waters from different pots do not show a greater variation than 5 per cent.

SUMMARY AND CONCLUSIONS

The results of drainage and leaching trials carried out at Peradeniya in cylindrical galvanised iron pots containing 3 feet columns of filled soil, during 1927 and 1928 and in a slightly modified form in 1929 indicate that:

(1) There is, in general, a definite positive correlation between the rainfall and drainage from the uncropped pots, if the rainfall is of such a magnitude that drainage does occur. This relationship is not so apparent in the case of the cropped pots. If the rainfall is low and well distributed no drainage occurs. Where the rainfall is heavy and continuous, the drainage from the cropped pots approximates to that from the uncropped pots.

(2) The amounts of fertilising constituents lost in the drainage from the uncropped pots are closely connected with the amounts of the drainage. The amounts of lime and nitrate are particularly large, but much lower quantities of the latter are found in the leachings in 1929 than in 1927 or 1928. The amounts of lime found in the drainage waters are still high though lower than those in 1927 or 1928. The occurrence of large losses of fertilising constituents in the drainage from uncropped, uncultivated and bare tropical soil under heavy rainfall conditions, is thereby indicated.

(3) The losses of nitrate nitrogen from the cropped pots show a marked fall during 1927 and 1928 and are practically nil in 1929. This would appear to indicate that when perennial bushy crops of root depth ranging up to three feet are grown in such a way as to cover the ground effectively, as in these experiments, the common *Hibiscus* being the crop chosen, only small losses of the nitrogen added in soluble fertilisers occur through leaching, even under heavy rainfall conditions. Fair quantities of lime continue to be lost, however, from these pots.

(4) The concentrations of nitrate nitrogen and lime in the drainage waters from the uncropped pots do not show more than a seven per cent. variation in the case of the former and five per cent. in the case of the latter, in spite of differential treatments. With the cropped pots the variations are larger.

(5) The 1927 and 1928 results indicate further, that, besides nitrates and lime, magnesia, chlorine and potash are lost from the soil in the drainage waters in decreasing order of magnitude.

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INFERTILITY IN IMPORTED PLANTS

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IT has probably been observed that very many of our garden plants, while being abundant flowerers in this country, do not produce fruit.

The reason for this phenomenon is by no means easy to find. It is sometimes put down to an unsuitable climate. "Climate," like "abnormal seasons," always comes in for a lot of credit, that perhaps belongs neither to the one nor to the other, but affords an excellent excuse when one does not know of a better. But really, *is* "climate" at the bottom of a great deal of the alleged causes of things; and what is an abnormal season ?

We know, or at any rate we say so, whether it is right or wrong, that self-preservation is the first law of Nature, and preservation of the species is the second. If we get down to thinking out what "preservation of the species" really means, we shall find it is a pretty large subject. If we think for a moment, it must include, in plants, what we understand by pollination, and if we throw our minds back a bit, we must come to the conclusion that this particular device must have gone a long way back in evolution before it reached the stage we understand today. It is only a natural deduction based upon the observation of undeniable facts that pollination must precede fruit formation, and fruit is only the envelope of the seed that later must form the individual plant or plants, that in turn will go through the same cycle of life once more. But we must not forget to notice that by the competition between plant and plant, there is some hidden power that asserts itself in the direction of securing the success of a particular individual, and what is more, the successful competitor will transmit to its offspring the same mode of success in order that the next generation may have a chance. Thus, we shall find by a little observation, that there are numberless devices by which seeds may be spread naturally away from the parent plant. These may be in the form of wings, parachute apparatus by which the wind can carry the seed to considerable distances; a strong fibrous casing, so that the fruit can be conveyed by water; hooks, which will attach themselves to ambulatory organisms; attractive colours so that fruits may be eaten and their enclosed seeds be transported by the bird or beast that devoured the fruit, and so on in endless variety. The lesson of all this is summed up in that short sentence—the preservation of the species—Nature's second law.

Now when we come to examine these very interesting methods for securing this preservation, we naturally expect to find it to exist without exception. Obviously if the struggle for existence developed these varied appliances for the preservation of the species, any exception to that progressive force would mean suicide, or something like it. We also observe that intense competition between plant and plant, not necessarily of the same species, brings about a state of equilibrium for a time, till some chance brings about a lessened competition, that is immediately counterbalanced by a fresh advance that will fill up that particular gap, and once more there is a temporary stable equilibrium. Suppose a plant, or its seed, is transported by some agency, artificial or otherwise, to a new country where it has no such competition as it had to meet in its native home, it will, in most cases, run riot and become a pest, till in turn it falls a victim to some superior force that suppresses it. In this way we find that many an introduced species practically "takes charge" for the time being, and wipes out its indigenous competitors. In other words the new arrival is freed from its competitors that kept it in check in its own country, and on being released from that strain it is, for a time, in what we might call a free field. We have many examples of this success of introduced species, as for instance Lantana, "White weed," Tridax, Mikania, etc., that we see all over the country, and which we know to be of comparatively recent introduction. Mikania, it may be interesting to observe, was introduced from Tropical America some 50 years ago. It "took charge" with remarkable rapidity, and is now up against an enemy in a *Cuscuta* that in parts of the country is completely crumpling it up.

But while it is easily comprehensible that a species freed from its counterbalancing competitors should become very prolific the moment those opposing factors are eliminated, it is very difficult to find a convincing reason why introductions are often sterile. We are not prepared to be satisfied with the answer that this is due to "climate," "abnormal" conditions, etc, until it can be so demonstrated. If the extraordinary success of a few introduced species is a proof that this "success" was due to an environment free from equilibriating competition, then we must look to some completely different conditions to account for sterility. Sterility is obviously the very opposite of all that goes for the preservation of the species, and yet the species is directly dependent on reproduction; so how are we to explain why a species that grows and lives, and flourishes abundantly is unable to reproduce itself ?

It might be supposed that certain insects that convey pollen are absent, and for that reason the flowers are not fertilised. Similarly, some will contend that the absence of *Thrips*—so

much suspected of being the conveying medium of intensely minute pollen—is an explanation; but somehow these explanations are not convincing, any more than the "abnormal season" will fully explain a bad Profit and Loss Account to anxious shareholders.

Let us consider some familiar examples of introduced plants, and note the peculiar state of things, bearing in mind the corresponding number of allies there are to be found in the country, so that we may make sure that sterility is not due to an absence of family connexions. I think this is of importance and might be worthy of consideration.

Take the *Solanaceae*, as a fairly well-represented order in Ceylon, and one that has several introduced forms. Of these, let us take the Potato Tree as an erratic fruiter. This plant—*Solanum Macranthum*—was introduced into Ceylon from Brazil in 1844. It flourishes here and flowers very abundantly, but it fruits very badly, sometimes never producing a single fruit from one year's end to the other.

Datura Suaveolens, or Devil's Trumpet flower, is another Peruvian or Mexican species that was introduced probably long before the last named. It flowers here in abundance, but only very rarely does it fruit, though *D. fastuosa* (Attana of the Sinhalese) rarely fails to fruit. In the former, the flower generally opens at night, when its scent is most powerful, and in the latter the flowering is not confined to darkness. Some will jump at this as the explanation, but in reply I have only to say that I have freely found insects that appear to have been drawn by the scent of *D. Suaveolens*, and I have found a few fruits, so that this does not appear to be a completely satisfactory reply to the question why *D. Suaveolens* is practically a non-fruiting species. Our local Solanums cannot be accused of sterility, as anybody who pleases can satisfy himself of their remarkable fecundity by examining any of our common examples.

Let us turn to our magnificent *Allamanda cathartica*, one of the *Apocynaceae*, which flourishes most vigorously in a great part of this Island. It flowers copiously all the year round, but it is exceedingly unusual to find it in fruit. It is a native of Brazil, and of very long introduction, so much so that it is well known by its Sinhalese name of Wal-rukkattana, and it may claim to be now almost natural in this country. Its close ally *A. Schottii*, also a native of Brazil that was introduced here in 1850, fruits abundantly. The family is very well represented here, as we have no less than 19 genera and 25 species, of which 8 are endemic. But perhaps the most remarkably unfruitful example of this order is the widespread Temple Tree (*Plumeria acutifolia*), so familiar to us all as associated with Buddhist places of worship.

It is a native of Tropical America, but when it was first introduced into Ceylon there is no record. After seeking for fruits of it for many years, I first collected some pods from a single tree growing at Rakwana. Comparatively recently, through the kindness of the late Mrs. Sinclair, I obtained a second pod, and the seeds were grown at Peradeniya Botanic Gardens, one plant of which I have, and this produced flowers this year, but no fruit. The general colouring of the flower so produced makes one feel sure that my plant is a cross between *P. acutifolia* and *P. rubra*, which latter is a fruit producer as well as a comparatively modern introduction.

For some obscure reason, *P. acutifolia*, though it is to be found flourishing in both dry and moist districts, is practically a non-fruiting species, but can be always easily grown from cuttings. My first pod, I may mention, was produced before *P. rubra* was known in Ceylon, and Mrs. Sinclair's specimen came from a tree, one branch of which (the one that fruited) had been injured, and in its vicinity were flowering examples of *P. rubra*.

It may be suggested, that the fact that Mrs. Sinclair's plant had been injured, had something to do with its fruiting, as in another case to which I shall refer; but I think we may safely say that we do not know the exact reasons for sterility.

Our much beloved Honeysuckle (*Lonicera citriodora*), as far as I know, never fruits in Ceylon, yet it is distributed widely. It belongs to the *Caprifoliaceae*, an order which is only represented by one genus and 2 species in Ceylon, a fact that may have some bearing on its unproductiveness.

Another very familiar plant is *Bignonia Venusta*, perhaps better known by its appropriate Tamil name of Tanga-poo or gold flower. This is most prolific in its flowering, but I have not met with a single fruit.

It certainly thrives very well here. Its native country is Brazil, and it was introduced here about 78 years ago. The family to which it belongs—*Bignoniaceae*— is not rich in native genera in Ceylon, being confined to 3, with a total of 3 species, none of which are endemic. We have several imported *Bignonias*, one of which, *Jacaranda mimosaefolia*, is very popular in Ceylon, its bluish-purple bell-shaped flowers being regarded as exceedingly attractive. Like the last named it is a native of Brazil, and was introduced here in 1886. Its fruiting is capricious. I have found it most prolific in one garden in Colombo with poor soil, while in another, though it is feasted and fed with manure and producing flowers in abundance, bears no fruits.

The *Acanthaceae* are a particularly well represented family in Ceylon, where we have 28 genera and 93 species, of which 19

are endemic. We have also a very large number of introduced plants belonging to this handsome order, one of which I will specially select, as it is so well known both up-country and at sea-level. This is *Thunbergia grandiflora*. I am uncertain as to when it was first introduced, but it is Malayan in origin. It flowers in profusion, and the flowers attract Carpenter Bees and small black ants, but it rarely produces fruit, except in a curiously erratic manner.

I have found it fruiting abundantly in one part of Colombo, and not in another. I have obtained fruit from a single plant growing on hard quartzite soil at 4,000 feet altitude, while at a place in the Kelani Valley where it had a rich soil, it grew in wild luxuriance and appeared to be completely sterile.

The order to which the Thunbergia belongs includes our familiar "Nellu," so characteristic of our hill-country vegetation. It might be suggested that as Nellu does not produce fruit yearly that may be the reason why our prolific flowering Thunbergia does not commonly do so. This suggestion however scarcely holds good, because Nellu, unlike Thunbergia, does not flower annually, and it is unlikely that its flowers are only fertile at long intervals.

Returning to the matter of unfruitful plants, and certain conditions of fruit production, I venture to give two instances that appear to justify certain deductions.

Spathodea campanulata—another of the *Bignoniaceae*—is a familiar plant in Ceylon owing to its attractive flowers. It is of comparatively modern introduction from western tropical Africa, having been introduced here in 1873. It flowers profusely, but does not always fruit, especially if it is growing in free rich soil. If the roots get congested by being among rocks, or otherwise retarded, it fruits in abundance.

Pisonia morindifolia belongs to Malaya, and was introduced about 90 years ago into Ceylon, and has been considerably planted for ornament in the low-country. I have only once succeeded in getting its flowers, though I have sought for it for many years. In this case, the tree I found flowering in Colombo had had its roots very severely cut about, and the whole tree looked as if it were going to die. It had shed most of its leaves, but it was in this debilitated condition that it flowered. Unfortunately, the owner of the tree, believing that the plant was going to die, had it cut down and removed, so that I was unable to follow it any longer.

These two examples suggest that there is some correlation between a physiological shock and the reproduction of species, the dying parent uses its last vital effort as it were to preserve the species.

CONTRIBUTIONS FROM THE RUBBER RESEARCH SCHEME, CEYLON

REPORT ON THE MARKET POSSIBILITIES OF FRACTIONALLY COAGULATED CREPE

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THE demand for a pale sole crepe has led to the extensive use of processes of fractional coagulation in which the bulk of the colouring matter in the latex is removed with the first fraction, so that the second fraction is of a very light colour. The Chemist in Ceylon (Mr. T. E. H. O'Brien) suggests that estates having difficulty in preparing standard crepe with an appearance which satisfies the market, might find it profitable to adopt the fractional coagulation method as employed in factories producing sole crepe. Under the conditions specified for Ceylon[1] the first fraction amounts to about 10 per cent of the whole and is sold at nearly 1d. per lb. less than standard crepe on account of its dark colour.* The remaining 90 per cent is of such good appearance that it will undoubtedly obtain full market price.

According to de Vries[2] "Partial coagulation was systematically applied in former years on some estates" in Java. The method of coagulation was not identical with that proposed in Ceylon and the first fraction amounted to 20 to 25 per cent of the total rubber in the latex. The second fraction did not command a premium to compensate for the low market value of the first fraction and, according to de Vries, "the method proved unprofitable and is therefore seldom applied." It is possible however that the method may prove profitable on an estate which has difficulty in obtaining full market price for its first grade crepe, particularly if coagulation conditions are so arranged that the dark coloured first fraction does not amount to more than 10 per cent of the whole.

It was considered by Mr. O'Brien that it would be desirable to compare the properties of the first and second fraction rubber as regards vulcanisation, plasticity, etc., in order to determine whether the market grading of the rubber is in accordance with its intrinsic value, and for this purpose samples were forwarded to the Imperial Institute for examination.

* *Note.*—In a valuation given by a Colombo Broker, March 1929, it was stated that "Sample B (first fraction rubber) should sell at about 3½ cents below standard quality price, on a reasonable market of the present value (45 cents)."—T.E.H.O'B.

The following is a report from a firm of London brokers to whom samples were submitted by the London Advisory Committee of the Scheme.

"As far as the London market is concerned, Samples Nos. 1458* and 1459* are of the same value; No. 1459 is of such white quality, however, that if it was sold here in bulk, it might in course of time command a slight premium over Standard Crepe, say $\frac{1}{8}$d. per lb.

No. 1460* is far below Standard and although the quality of the rubber may not be affected, it would not meet with a very good demand on the London market, except at a considerable discount."

The broker's report indicates that it will be difficult to obtain a premium for the pale second fraction and that even though the intrinsic qualities of the first and second fractions are the same, the dark coloured fraction will not command the same price as the light coloured fraction.

It was considered by the London Committee however that if it could be shown that either or both fractions were peculiarly suited for definite manufacturing purposes, it might be possible to interest manufacturers in this method of preparation and to create a special demand which should eventually be reflected in price. For example, the pale second fraction should be particularly suitable for the manufacture of transparent dipped goods such as teats, which have to satisfy a market equally as exacting as regards appearance as that for plantation rubber.

Two sets of first and second fraction crepes prepared by Mr. O'Brien in Ceylon have now been examined by the London Staff of the Scheme, and in view of the results obtained an important British manufacturer has agreed to try the first fraction for the manufacture of vulcanised tape and the second for transparent dipped goods. Arrangements have also been made with the Research Association of British Rubber Manufacturers and the Electrical Research Association for the inclusion of the second fraction rubber along with other types in an investigation which has as its object the preparation of ebonite with improved properties.

The samples examined were in the form of blanket crepe and consisted of a control sample and fractionally coagulated material. The control sample was prepared by coagulation in the usual way. The first fraction was prepared without the addition of acid by allowing the diluted latex containing bisulphite to stand overnight. At the end of this period it was stirred vigorously for an hour and the first clot removed and treated in the usual way. The remaining latex was treated with acid and the coagulum machined as usual.

* 1458—Control. 1460—1st Fraction, 1459—2nd Fraction.

On arrival in London the first fraction crepe was brownish-yellow, whilst the second fraction crepe was very light in colour, being slightly paler than the control sample. The dark colour of the first fraction is due to carotin[3] (the yellow colouring matter of carrots). It is removed on extraction with acetone, the extracted rubber being much paler than the original. The following results show that the first fraction contains a much larger proportion of substances soluble in acetone than the second, but it is not suggested that this is due to the different amounts of carotin in the two fractions as carotin only forms a small proportion of the substances soluble in acetone.[3]

De Vries[4] also stated that the first fraction rubber contains a higher percentage of nitrogen and mineral matter. These additional quantities of non-caoutchouc substances not only affect the colour of the first clot but also its vulcanising and ageing properties, as shown by the following results of tests:

	Acetone Extract	
	1st series per cent	2nd series per cent
Control sample	3·05	3·28
First fraction	5·36	7·08
Second fraction	2·80	3·04

(a) Vulcanisation Tests

Series	Sample No.	Description	Rubber-sulphur mixing.	Time of vulcanisation at 148°C.	Tensile Strength	Elongation		Maximum tensile strength	Time of vulcanisation required for	
						At load of 1·00 kgs./sq. mm.	At load of 1·04 kgs./sq.mm.		$E_{1·00}=800$ per cent	$E_{1·04}=775$ per cent
				(mins.)	(lb./sq. in.)	(per cent)	(per cent)	(lb./sq. in.)	(mins.)	(mins.)
First	1458	Control	100 :10	120	1850	840	—	2220	131	—
				140	2220	771	—			
,,	1460	First fraction	,,	80	1880	850	—	2150	90	—
				100	2150	752	—			
,,	1459	Second fraction	,,	120	1880	685	—			
				120	2100	825	—	2340	126	—
				140	2340	746	—			
Second	1490	Control	90 :10	100	1480	—	906	2150	—	130
				110	1980	—	837			
				120	2170	—	800			
				130	2150	—	775			
				140	2250	—	743			
				150	2370	—	705			
				160	940	—	681			
,,	1491	First fraction	,,	40	1350	—	—	2260	—	76
				50	1570	—	909			
				58	1930	—	840			
				70	2080	—	800			
				80	2260	—	758			
				90	2200	—	713			
				100	1800	—	692			
,,	1492	Second fraction	,,	100	1630	—	867	2240	—	126
				110	1970	—	823			
				120	2120	—	800			
				130	2140	—	763			
				140	2130	—	712			
				150	2240	—	686			
				160	1260	—	653			

The following points in connection with the above results are of interest:

1. The dark coloured first fraction vulcanises in a little over half the time of the control sample and of the second fraction.

2. The second fraction vulcanises slightly faster than the control but the difference is of no practical importance.

3. All three samples have good tensile strengths.

4. The first fraction maintains good tensile properties over a much wider range of "cures" than the other samples, regard being paid to the relative rates of vulcanisation. This test was performed on the second series of samples only. The results are shown in a comparable form in the following table:

Sample No.	Description	Range of cures for which strength exceeds 1,500 lb./100 x sq. in.
		Correct cure
1490	Control	39
1491	First fraction	> 66
1492	Second ,,	40

(*b*) *Ageing Tests.*—Vulcanised test rings were kept circulating in air at 70°C and removed after periods of 48, 96 and 144 hours. The following are the results of tests on the aged samples:

Series	Sample No.	Description	Time of vulcanisation	Period of artificial ageing	Tensile Strength	Elongation at load of 1·04 kgs./sq. mm.
			(mins.)	(hrs.)	(lb./sq. in.)	(per cent)
First	1458	Control	100	nil	1780	872
				48	2060	794
				96	1860	755
				144	1700	730
Second	1490	,,	110	nil	1760	850
				48	2280	766
				96	2060	719
				144	1780	690
First	1460	First fraction	60	nil	1450	878
				48	2170	804
				96	2280	791
				144	2010	770
Second	1491	,, ,,	58	nil	1930	840
				48	2480	742
				96	2490	698
				144	2240	669
First	1459	Second fraction	98	nil	1580	866
				48	2260	794
				96	2020	754
				144	1800	731
Second	1492	,, ,,	100	nil	1760	864
				48	2420	772
				96	2260	719
				144	950	695

There is little difference between the ageing properties of the second fraction and of the control sample. The ageing properties of the first fraction are superior because it retains its tensile strength for a longer period.

(*c*) *Plasticity Tests.*—The results of plasticity tests are shown in the following table:

Series	Sample No.	Description	Unmasticated rubber D_{30}	Mastication number
First	1458	Control	154	99
,,	1460	First fraction	161	101
,,	1459	Second fraction	154	95
Second	1490	Control	161	92
,,	1491	First fraction	156	90
,,	1492	Second fraction	156	89

There is little difference in the plasticity of the three samples. This is somewhat surprising as the first fraction contains more non-rubber accessory substances than the others and the freshly rolled crepe before drying was very weak, displaying poor coherence.

REMARKS

The first fraction crepe might be regarded as inferior to the others not only on account of colour but also because it represents a less pure form of caoutchouc. The additional accessory substances however not only enable the rubber to vulcanise quickly but also to maintain a good tensile strength over a wide range of cures and for a long ageing period. These properties may be of value in connection with the manufacture of tape.[5]

There is little difference between the second fraction and the control sample except in colour. Pale raw rubber should be of value for the manufacture of transparent goods.

An attempt is being made to interest manufacturers in the pale rubber and also in the highly coloured first fraction.

REFERENCES

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2. Estate Rubber, 1920, p. 389.
3. Eaton and Fullerton,—*Rubber Research Institute of Malaya Quarterly Circular* 1, 3, p. 135.
4. Estate Rubber, p. 390.
5. Twiss and Jones.—J.S.C.I. *42*; 1923, p. 505T.

A PRELIMINARY INVESTIGATION OF THE EFFECT OF DIFFERENT CONDITIONS OF STORAGE ON THE HARDNESS OF RAW RUBBER

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ONE of the factors affecting the reliability of plantation rubber is its variability in plasticity. Some consignments require more milling than others to reduce them to the plasticity required for manufacturing operations. If first grade rubber were uniform in this respect it would tend to increase the demand for this quality of material at the expense of more variable types (Special Circular March, 1930: "Value to Rubber Growers of the Work in London of the Ceylon Rubber Research Scheme.")

De Vries (Trans. Inst. Rubber Industry 1927, 3, 284) has shown that there is little variation in the hardness of first grade rubber soon after preparation, but that differences arise subsequently due to changes in the rubber during the period between its preparation and use by the manufacturer, specimens sometimes becoming harder, sometimes softer and sometimes showing little change. He concludes that the change is on the whole dependent upon the serum substances in the rubber, and that an excess causes hardening and a deficiency softening. The relation between the hardness of unmasticated or unmilled rubber and the amount of mastication required is not fully known, but information on this point is being obtained in London by the staff of the Ceylon Rubber Research Scheme.

Temperature.—The samples examined in London in connection with the work of the Ceylon Rubber Research Scheme on the effect of methods of preparation on plasticity are always stored for 6 months at 60°F after their arrival in London, so that changes have ample time to develop and the differences between samples correspond with those occurring in commercial operations. As rubber on its journey from the East and while in Europe and America is subjected to a wide variety of temperature conditions, most of the samples received for examination have lately been stored at 32°F as well as at 60°F before testing. The samples stored at 32°F are invariably "frozen," (*i.e.*, they

become opaque and very hard) and some of those stored at 60°F also become "frozen," but on warming or masticating they all quickly become translucent and supple, and their "frozen" condition appears to have no effect on the results of either mastication or hardness tests. On the whole the samples stored at 32°F are slightly softer and require slightly less milling to reach a fixed degree of plasticity than those stored at 60°F.

It is proposed to extend the investigation to the effect of storage at higher temperatures as, in practice, rubber is subjected for a time to tropical temperatures and may also be exposed to very high temperatures during transport and whilst in Europe and America.

Humidity.—Not only is the rubber of commerce exposed to a variety of temperatures but also to a wide range of humidity conditions. In the tropics the atmosphere is mostly damp; in Europe and America the amount of moisture in the atmosphere is much less but is subject to considerable fluctuations. A preliminary series of experiments was therefore arranged to determine the effect on hardness of storing rubber at 60°F for a considerable period in atmospheres containing different amounts of miosture.

The samples were stored for 11 months in glass jars and exposed to air at 60°F containing different amounts of moisture as follows:—(a) dry, (b) 38 per cent saturation, (b) 80 per cent saturation, (c) 96 per cent saturation. All the jars were kept in a moderately dark room, but as they were exposed to a dull light which might have some effect on hardness an additional set of samples was stored in a jar containing air 80 per cent saturated with moisture, and totally enclosed so as to exclude all light.

The different amounts of moisture in the atmosphere required for these experiments were obtained by sulphuric acid of the required concentration. As sulphuric acid vapour might have an effect on the hardness of the rubber a further set of samples was stored over calcium chloride for comparison with that stored over concentrated sulphuric acid.

The samples consisted of ten smoked sheets which had been prepared by allowing the coagulum to remain in the serum for different periods. They were all prepared from the same latex but in the case of five of them the coagulant was acetic acid and paranitrophenol, and in the case of the other five acetic acid only was used for coagulation. The test was only regarded as a preliminary one to indicate whether the subject was worthy of detailed attention and there was no particular reason for selecting these samples beyond that of convenience.

The results are shown in the tables appended to this report; the higher the results (D_{30}) the harder is the rubber. The hardness figure for most samples of first grade rubber is between 140 and 200.

As the length of time the coagulum remained in the serum seems to have had no effect on the results of hardness tests, it is convenient to compare the average results for each set of five samples, which are shown in the following tables:

EFFECT OF STORAGE FOR 11 MONTHS AT 60°F.

(a) Different conditions of moisture

Samples	Before Storage	After Storage				
		Dry		38 per cent moisture	80 per cent moisture	96 per cent moisture
		Concentrated sulphuric acid	Calcium chloride	50 per cent sulphuric acid	25 per cent sulphuric acid	10 per cent sulphuric acid
	D_{30}	D_{30}	D_{30}	D_{30}	D_{30}	D_{30}
	mm./100	mms./100	mms./100	mms./100	mms./100	mms./100
Not containing paranitrophenol	157	181	177	167	159	174
Containing paranitrophenol	155	187	178	163	158	163

(b) Different conditions of light (humidity 80 per cent saturation)

Samples	*Before Storage*	*After Storage*	
		Diffused light	Dark
	D_{30}	D_{30}	D_{30}
	mms./100	mms./100	mms./100
Not containing paranitrophenol	157	159	161
Containing paranitrophenol	155	158	161

On an average all the samples became harder on keeping. Those stored in a dry atmosphere (over concentrated sulphuric acid or calcium chloride) became very hard, and the wetter the atmosphere the less the change in hardness except in the case of those samples stored in a very wet atmosphere. Some of these were as hard as samples stored in a dry atmosphere, but as they had become mouldy and the hardness was proportional to the

amount of mould present it is concluded that the hardness of these samples was due to secondary changes. The samples containing paranitrophenol did not become as mouldy as the others, and it will be observed that they are much softer although on the whole, in other cases, paranitrophenol had little effect on the hardness of the rubber.

Prolonged exposure to very dull diffused light had no effect on the hardness of sheet under the moisture conditions selected.

It is evident from these preliminary experiments that changes in the hardness of rubber on keeping are markedly affected by the amount of moisture in the atmosphere. It is proposed therefore to carry out more detailed work and also to study further the effect of mould on plasticity.

Oxygen.—As a matter of theoretical interest duplicate portions of the same samples were stored at 60°F in sealed tins in oxygen and nitrogen without any control of the humidity. Only the samples stored in nitrogen failed to harden. Further tests are necessary before it can be concluded that changes in hardness on keeping do not occur in the absence of oxygen. The results obtained are shown below.

Samples	Before Storage	After Storage	
		Oxygen	Nitrogen
	D_{30} mms./100	D_{30} mms./100	D_{30} mms./100
Not containing paranitrophenol (average)	157	168	153
Containing paranitrophenol (average)	155	162	153

Table A

After storage for 11 months

Sample No.	Coagulant	Period Coagulum left in serum	Before storage	Concentrated sulphuric acid (dry)	Calcium Chloride (dry)	50 per cent sulphuric acid (38 per cent solution)	25 per cent sulphuric acid (80 per cent saturation) dark	light	10 per cent sulphuric acid (96 per cent saturation)	Oxygen	Nitrogen
		(hrs.)	D_{30}	D_{30}	D_{30}	D_{30}	D_{30}	D_{30}	D_{30}	D_{30}	D_{30}
			mms./100	mms./100	mms./100	mms./100	mms./100	mms./100	mms./100	mms./100	mms./100
1385	Acetic Acid	4½	154	177	168	158	155	161	174	165	147
1386	,, ,,	17¾	158	180	170	169	160	158	169	163	157
1387	,, ,,	35½	156	182	180	169	160	160	176	174	154
1388	,, ,,	40¼	156	183	178	168	163	155	182	167	153
1389	,, ,,	55½	159	182	187	169	165	160	171	169	155
1390	Acetic acid and paranitrophenol	4½	151	190	178	169	164	161	163	167	153
1391	,, ,,	17¾	158	184	183	161	161	160	160	164	152
1392	,, ,,	35½	155	174	171	166	156	155	165	160	148
1393	,, ,,	40¼	156	194	189	161	160	156	168	157	155
1394	,, ,,	55½	155	192	171	159	164	160	157	161	159

SULPHUR DUSTING AS A MEANS OF CONTROLLING OIDIUM*

A STATEMENT MADE AT THE GENERAL MEETING OF THE RUBBER RESEARCH SCHEME ON APRIL 25, 1930

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Introduction.—The experiments which the Rubber Research Scheme is carrying out on the control of *Oidium* leaf disease by means of sulphur dusting have not yet reached a stage at which a detailed report may be issued. In view, however, of the interest in the method which planters and agents are now showing, as evidenced by a number of enquiries received during the last few weeks, it was thought that a statement made at this meeting would be of value. The following is therefore in the nature of a brief interim report, summarising the method of procedure and the results so far achieved. It may at once be stated that although we have not secured the 100% degree of control claimed for the treatment in Java, the experiments which have so far been carried out give promise that the method will prove to be an effective and economical means of control in Ceylon.

The photographs attached illustrate the dusting process and the results achieved, and are readily understood by reference to the explanatory footnotes.

MATERIALS

(a) *Dusting Machine.*—In the experiments referred to a machine imported from Java has been used. It is hoped to carry out a comparative test with a machine of British manufacture at an early date, and until the results of this trial are available no official recommendation as regards the most suitable machine can be made.

In the Dutch machine a small petrol motor drives a fan at high speed. The sulphur is fed into the fan chamber from a hopper with a feed regulator, and is blown up through a chimney. The whole forms a compact unit easily portable by coolies.

(b) *Sulphur.*—The sulphur that has been used is Kawah Poetih volcanic sulphur from Java. This is sold in two grades of which the higher grade, known as "Flotate" sulphur, has been used. This dust contains 90-95% sulphur (on dry

* Issued as Leaflet No. 11 of the Rubber Research Scheme (Ceylon).

sample) with a maximum moisture content of 5%. It is necessary to dry this sulphur before use by spreading it out in the sun for a few hours. The sulphur is very finely divided and has excellent cloud-forming properties. It is obtainable from N. V. The Estates Supplies Co., Ltd., Sourabaya, Java, at a cost of F 100/- per 1000 Kg. (About -/06 cts. per lb. in Ceylon).

The Dusting Operation.—Sulphur is fed into the hopper, the machine is swung with the starting belt, and the dusting is in progress. The machine is carried, while working, along suitable paths or lines, the output of sulphur being adjusted according to the strength of the wind, the slope of the land, and the rate of progress. It is usually possible to do most of the dusting from paths or roads. A gang of ten or twelve coolies is sufficient according to the nature of the ground; four coolies to carry the machine, one to keep the hopper constantly half-full of sulphur, and the remainder to bring the sulphur to the machine from pre-arranged dumps.

The distance to which the sulphur carries, and therefore the working range of the machine, depends largely on the strength of the wind. With no wind the sulphur rises very high in the air and the process is very slow. A strong wind is unfavourable unless blowing down a steep slope since the sulphur does not then rise satisfactorily to the tops of the trees. The ideal conditions are a very slight steady breeze which permits the sulphur to rise to a sufficient height, and at the same time wafts it slowly through the foliage. Under these conditions the machine has an effective range of action of about 100 yards. Under Ceylon conditions an average area of 100 acres should be covered in a day.

The Experiments in Matale.—Experiments on sulphur dusting have been carried out on Bandarapola and Kandanuwara estates, Matale, the rubber being very severely affected with *Oidium*. On the experimental 100 acres on Bandarapola three applications of sulphur were made, while on Kandanuwara a field of 30 acres was treated with five dustings. The results secured on Bandarapola were disappointing, and indicate that insufficient applications were made. Attention is drawn to the experiments on Kandanuwara.

On the experimental area five applications of sulphur were made at approximately 10-14 day intervals during the period of refoliation after wintering. A total quantity of 1,600 lb. of sulphur was used which averages approximately 10½ lb. per acre per application. A neighbouring field of equally affected rubber served as a control.

Owing to a number of causes which need not be discussed here 100% control of *Oidium* on the dusted area has not been

Plate I.—The Dusting Machine—12-3-20.

Plate II—Kandanuwara Estate. Dusting in progress—20-2-30.

Plate III.—Kandanuwara Estate. Dusting in progress with machine in motion—22-1-30.

Plate IV.—Kandanuwara Estate,
Dusting in progress. Machine at rest —12-3-30.

Plate V.—Kandanuwara Estate. Dusted field after four applications—11-3-30.

Plate VI.—Kandanuwara Estate. Undusted control field—11-3-30.

Plate VII.- Kandanuwara Dusted field after four applications—11-3-30.

Plate VIII.—Kandanuwara Estate. Undusted control field—11-3-30.

secured. The photographs, however, indicate that the foliage of the dusted rubber is markedly superior to that of the undusted control area.

As an additional means of judging the results of the dusting the foliage of a number of individual trees in small plots scattered throughout the dusted and control fields was classified according to the intensity of *Oidium* attack. 156 trees were so examined in the dusted field, and 150 trees in the control field, the examination being made in April after the wintering was completed. In the dusted field 11% of the trees were classed as completely defoliated, while in the control area the figure was 53%. Correspondingly 20% were almost free from the disease in the dusted as against 3% in the undusted area.

Yield records are being taken in the dusted and undusted fields but no results are yet available.

Quantities and Costs.—The cost of the dusting on the 30 acres of Kandanuwara estate was high owing to the smallness of the area and the disproportionate cost per acre of the labour. The following is a sample of the cost of one day's dusting on the basis of 100 acres per day:

	Rs.	cts.
1,200 lb. sulphur @ -/06 cts. per lb. ...	72	00
4 coolies to carry duster @ -/60 cts. ...	2	40
6 coolies carrying and feeding sulphur ...	3	60
1½ gallons petrol-oil mixture ...	3	00
	81	00

On this basis the cost works out at -/81 cents per acre per application, excluding depreciation on the machine and special supervision. It will be seen that the cost lies almost entirely in the sulphur, the labour and the running expenses of the machine being very small items.

Discussion.—Such questions as the minimum effective quantity of sulphur per acre, the number of applications necessary and the period elapsing between successive applications must be subjects for further investigation, and will depend largely on the degree of attack. It is also not known whether dusting will be a permanent cure or whether it will be necessary to carry out the treatment every year. The method has the advantage of being quick and comparatively cheap, and it is hoped that further dustings may achieve a higher degree of control than the first experiments.

Acknowledgment.—In conclusion, I should like to express my gratitude to the superintendents of Bandarapola and Kandanuwara estates whose assistance has been of great value.

THE COCONUT INDUSTRY

[The following memoranda supply further explanations to the report on the coconut industry submitted to the Government of Fiji by the Empire Marketing Board and which was reproduced in *The Tropical Agriculturist*, Vol. LXXIV, No. 3 p.143 (1930). We are indebted to the Agricultural Advisor to the Secretary of State for the Colonies for copies of them.—Ed., *T. A.*]

PRODUCTION OF COCONUTS

TABLES A, B, and C attached give statistics which have been compiled in the Imperial Institute regarding the domestic exports of (i) Coconuts, (ii) Copra, and (iii) Coconut Oil from the producing countries in the Empire for the four years 1925-1928 so far as information is available, and also the corresponding figures for the Dutch East Indies and the Philippines.

In order to secure a correct impression of the growth or decline of the coconut industry in the various countries, it is necessary to bring the figures given in these tables to a common denominator, and a further Table D has therefore been prepared shewing the total exports of coconuts, copra, and coconut oil in terms of coconuts. For this purpose one ton of coconut oil has been regarded as equivalent to 8,125 nuts. Where exports of coconuts have been given in tons, one ton has been taken as equal to 1,400 nuts.

It will be seen that Table D does not include exports from the Straits Settlements or the Unfederated Malay States, which are shown in the preceding tables, nor have the exports of coconut oil from Australia been included for the reason given in note (b) to Table C.

PROSPECTS OF THE COPRA INDUSTRY

1. Average prices per ton of Federated Malay States Singapore Copra c.i.f. London, during recent years have been as follows:

Table I

Annual average prices of copra

Year	Price per ton £	s.	d.	Year	Price per ton £	s.	d.
1916	33	13	9	1923	27	17	6
1918 (controlled)	45	10	0	1924	29	15	0
1919	52	10	0	1925	30	5	0
1920	56	7	6	1926	28	12	6
1921	30	12	6	1927	27	10	0
1922	24	15	0	1928	26	17	6
				1929	23	1	0

2. Changes in quotations for copra during the past three years are shown below:

Table II

Variations in copra prices 1926-1928

	£	s.	d.		£	s.	d.		£	s.	d.
1926 January	29	7	6	December	26	2	6	*Fall*	3	5	0
1927 ,,	27	2	6	,,	28	7	6	*Rise*	1	5	0
1928 ,,	28	12	6	,,	25	0	0	*Fall*	3	12	6
1929 ,,	24	7	6	,,	22	12	6	*Fall*	1	15	0

During 1929, the price fell to £21 in June but rose to £23 in the following month. Although £24 was recorded in September, the price fell again in October, and the average for December was £22. 12. 6. The continued low prices are partly attributable to the prospect of feeding stuffs other than oil cake being in plentiful supply.

3. There has of course been a very substantial increase in the production of copra in comparison with pre-war years. The following figures extracted from the Year Book of the International Institute of Agriculture (with certain later figures where available) show the average nett exports of copra in the quinquennium 1909-13, and during the past five years, with separate particulars for the five groups of countries which together account for some 90 per cent. of the quantities entering world trade.

Table III

World Exports of copra

	1909/13	1924	1925	1926	1927	1928
	Thousand tons		Thousand tons		Thousand tons	
Total	545	875	907	1008	903	—
British Malaya	4	92	86	104	87	95
Dutch E. Indies	234	338	335	371	300	431
Philippines	128	154	145	171	196	234
Ceylon	41	88	113	121	99	99
South Seas	70	139	148	159	159*	—

* Provisional

4. The high prices ruling for copra in 1919 and 1920 resulted in an increase in coconut plantations. After the slump of 1920/21 prices rose from 1922 to 1925 and it was not until 1926, when the new plantations begun to come into bearing, that the increase in world supplies showed signs at outstripping the increase in demand. World supplies in 1927 fell back to about the 1925 level and it is noticeable that there was some appreciation in values during the year, but although complete figures for 1928 are not yet available, there was evidently a striking recovery in supplies in that year, four groups of countries, which together account for 75 per cent. of the world's exports, having an export 12 per cent. in excess of the 1926 total and 26 per cent. higher than in 1927. Information obtained from trade sources indicates that during the first quarter of 1929 world shipments showed a further appreciable increase over the corresponding period in 1928, but that there was a decline during the second quarter. These fluctuations are reflected in the varying quotations for copra during 1929, given in paragraph 2 above.

5. It appears, therefore, that the fall in copra prices during the past 1½ years has been partly due to increased production, following the high prices, and consequent new plantings, in 1919/20. The majority of new plantations established during these two years are presumably now in bearing and although production may be expected to continue to increase for a year or two, there is every probability that the rate of increase will tend to slow down. On the other hand, there is reason to believe that the consumption of copra will continue to increase owing to the growth of population and the increasing use of vegetable oils.

6. With regard to competitive products, it is no doubt true that the increased production of groundnuts and whale oil, both of which are largely used in margarine making, has contributed to the depression in the copra market, and the increased world production of other vegetable oils is doubtless a further contributory factor. World exports of groundnuts during pre-war and recent years are given in Table IV below:

Table IV

World exports of groundnuts

	1909/13	1924	1925	1926	1927	1928
	Thousand tons		Thousand tons		Thousand tons	
Total	*555*	*992*	*1333*	*1377*	*1293*	—
British India	192	243	463	444	457	749
Fresh W. Africa	205	312	444	480	404	386
British W. Africa	64	139	176	188	160	195
China	39	196	168	176	—	—

7. It is of course impossible to foretell with any degree of accuracy what may be the further trend in production of an annual crop such as groundnuts. Any continued depression in market values would presumably be followed in due course by a reduction in acreage under cultivation. As regards whale oil, figures of production, obtained from trade sources, indicate an increase from 109,000 tons in 1922 to 203,000 tons, in 1922 and 226,000 tons in 1928. Production in 1929 is expected to reach nearly 300,000 tons.

8. It is impossible to determine to what extent recent combinations of buyers and the creation of a margarine combine covering the great part of margarine production in this country and on the Continent, has affected the market for copra. It appears, however, that since both copra and palm kernels are more exclusively used for magarine than other oil seeds, their price depends to a larger extent on the buying policy of the margarine combine. When supplies are in excess of demand a combination of buyers may undoubtedly depress the market unduly to the disadvantage of sellers and has led in other industries to combination or co-operatiive selling on the part of producers.

9. The Board's Statistics and Intelligence Branch undertakes periodical surveys of the world position of certain commodities, and the question of a world survey of the production and consumption of oil seeds is now under consideration. The above information has been compiled on the basis of information already available in the publications of the International Institute of Agriculture supplemented by trade statistics, but it is hoped that more complete figures will be obtained as a result of the world agricultural census of 1930.

THE RELATION OF WEATHER TO PLANT DISEASES*

INTRODUCTION

THE object of this paper is to outline briefly the relation of weather to plant diseases, and to suggest methods by which the meteorologist can be of assistance to the plant pathologist. Plant diseases caused by parasitic agencies alone will be considered, and the discussion will be limited to diseases due to fungi and allied micro-organisms.

A century or more ago the diseases of crop plants were attributed directly and solely to adverse weather conditions. At a later period scientists, on discovering that certain micro-organisms were responsible for these diseases, concluded that the previously held view of the direct connection between weather and disease was entirely erroneous. Thus, seventy years ago, neither the plant pathologist nor the agricultural meteorologist realised the essential and true connection between weather conditions and the outbreak and spread of disease in cultivated crops. As the science of plant pathology developed, however, it became evident that in certain years some diseases were conspicuous by their severity and others by their mildness or even complete absence, this order being reversed in other years when different weather conditions prevailed. In more recent times, research on the relation between weather conditions and the prevalence of plant diseases has progressed remarkably as a result of studies made both in the laboratory and in the field. This "phenological" aspect of plant pathology is, nevertheless, still in its infancy; and not until much more extended data become available can the prevalence of epidemics in crops be correlated with certainty with specific weather conditions. What the plant pathologist really needs is a system of weather forecasting sufficiently detailed and accurate to enable him to advise growers that certain diseases are sure to appear, because the coming weather will be favourable to those diseases. Acting on such advice the grower would then be able to take such preventive measures as were possible to ward off attack.

That a definite connection exists between weather conditions and certain plant diseases can readily be seen in almost any season. In a small country such as England, where there are no wide variations in climate at any time, instances can be given of diseases being unusually prevalent in one year and absent in another. Amongst such diseases are those caused by the Powdery Mildews (*Erysiphaceae*), which became epidemic in the dry, hot summer of 1921. In that year, however, two diseases were noticeable for their comparative absence, namely, Potato Blight, due to *Phytophthora infestans,* and Yellow Rust (*Puccinia glumarum*) of Wheat. Such occurrences show that different diseases are affected differently by the same weather conditions. Countries of very extended area, such as the United States of America, present wide climatic variations; consequently the correlation of plant disease incidence with meteorological factors is more readily discernible.

* Paper read by C. E. Foister, B.A., of the Plant Pathological Division of the Department of Agriculture for Scotland, before the Agricultural Section of the Conference of Empire Meteorologists, 1929.

The various factors which comprise "weather" have been studied, most frequently separately, at some length. A few diseases, such as the Potato Blight and the Cereal Rusts, have been examined from the "collective weather" point of view, but it will be preferable to examine in what ways the individual factors influence the disease-complex first, and then to review and discuss those particular cases afterwards.

TEMPERATURE

In attempting to review our present knowledge of any individual factor such as temperature, it is still too early to explain fully the various phenomena observed. It must suffice here to indicate the phenological relations that exist; chemical and physiological explanations may be left for discussion amongst plant pathologists themselves.

It is natural to begin at a time antecedent to the appearance of a disease, that is, before the pathogen has attacked its host plant. It is now well known that, for the occurrence of an epidemic, it is not necessary for the fungus or other pathogen to be present at the outset in overwhelming numbers. It is sufficient if a small amount of the pathogen is present in a resting or latent form; for this, provided conditions are right, will develop and attack its host plant. Consequent upon this the secondary sources of infection (usually spores of some kind) formed by the pathogen when once established on the host plant, become distributed naturally, often by wind, to other plants. In this way the area of infection increases and an epidemic develops.

Temperature plays a very great part in the initial germination of the spores of the pathogen. In some cases it directly affects its survival through the winter or resting period. Often the survival of a fungus is imperilled by the weather conditions of the previous summer and autumn, which may prevent the formation of the very spores by which it normally survives the winter or such spores may actually be killed.

This occurred, for instance, at Cambridge during 1921, when the hot dry summer killed all the uredospores of *Puccinia glumarum,* so that during the winter of 1921 and the spring of 1922 no uredospores could be found. The writer personally noted the absence of this fungus, again, in the winter of 1926 and the spring of 1927, and there is little doubt that the summer weather of 1926 was, at least, partly responsible. Provided that the uredospores of *Puccinia glumarum* survive until the beginning of winter, they can easily survive further until the spring, since they are not injured by low temperatures. Miss Sampson collected uredospores of *P. glumarum* in Wales after from 3° to 8° C. of frost during the winters of 1922 and 1923, and found them capable of germinating. Marshal Ward found that the spores of *P. dispersa* on Bromes were killed by high temperatures (30° C), but that they survived freezing. Metha found *P. triticina* also capable of surviving freezing temperatures, but uredospores of *P. graminis* were killed by the lowering of the temperature that occurred in the middle of December. Another worker, Waterhouse, recorded the fact that the uredospores of *P. graminis* can survive the high temperatures of an Australian summer.

Again, temperature directly affects the germination of fungus spores. The spores of some fungi seem to need freezing before they will germinate. For instance, Salmon found that the spores of *Sphaerotheca Humuli* germinated better after freezing for twelve hours. Temperature also affects the type of spore germination in some cases. For example, in the Potato Blight fungus, *Phytophthora infestans,* high temperatures cause germ-tube germination but low temperatures cause zoospore liberation, although it must be admitted that temperature is not the only factor that determines the mode of germination of these spores. Melhus obtained optimum

zoospore liberation at from 12° to 13° C., but optimum germ-tube formation occurred at 24° C. The zoospores of this fungus remain motile for twenty-two hours at 5° to 6° C., while they remain motile for only nineteen minutes at 24°-25° C., thus diminishing the chances of infection at the higher temperature. Infection with the Potato Blight fungus is thus dependent upon relatively cool weather. Melhus obtained greatly increased infection when plants were chilled for twelve or twenty-four hours, to 10°-13° C. than when they were left at 21°-25° C. Gregory also found similar effects with *Plasmopara viticola,* the cause of Downy Mildew of the Grape. This disease starts in cool weather, owing to the fact that the resting spores do not germinate at 80°-90° F., while at 70° F. there is 40-50 per cent. and at 50° F. 95 per cent. germination. At 35°-41° F., however, there is hardly any germination. The zoospores also remain active longer at 50° F., as do those of *Phytophthora infestans.*

With Apple Scab (*Venturia inaequalis*), Keitt and Jones in the U.S.A. have studied the seasonal relations carefully. Possibility of infection begins as soon as the tips of the sepals emerge from the fruit-buds, and it lasts until from two to four weeks after petal fall. Again, although it may at no time be absolutely at a standstill, infection occurs readily in the autumn, when fruits and leaves may be attacked if cool moist weather occurs. Although the temperature range for infection is very wide (viz., from 6°-26° C.), the optimum is round about 20° C. The ascospores, curiously enough, germinate at temperatures of from 0·5°-32° C. It seems, also, that temperature has an influence upon the progress of the fungus in the tissues. Thus, at 8° C., the incubation period was prolonged to seventeen days, as compared with eight to twelve days at 20°-25° C. The disease developed sparsely after thirteen days at 26° C. in one trial, but failed to develop under similar conditions in two other trials. Nevertheless, it is a fact that the fungus tolerates summer temperatures in orchards much exceeding 26° C. It may be that the diurnal rise and fall in temperature has the same effect as a constant lower temperature. Keitt and Jones thought that the temperature range of the host plant exceeded that of the fungus. In any case, it seemed certain that the disease ranged within temperature limits approximating to those endured by the parasite.

Citrus Scab, caused by *Cladosporium Citri,* is a disease, the climatic relations of which can readily be studied, because the citrus fruit is grown in so many parts of the tropics that great variations in temperature are associated with its cultivation. Fawcett found that citrus foliage became infected only at relatively cool temperatures, viz., 16°-21° C., and that this range corresponded with the optimum for growth of the fungus in pure culture. Peltier and Peltier and Frederich found a similar range for infection, and correlated the seasonal appearance of the disease with climatic conditions. They found that the warm spring of 1918 in Alabama caused very early growth of the trees which, by the time the temperature reached that favourable for the fungus, had passed the susceptible stage; hence no Scab was reported there that year. The year 1915, however, was abnormally cold until much later in the season, and host growth was thereby retarded. When growth began, the temperature was also favourable for infection, hence Scab was prevalent in that year. In Manila (Philippine Islands) there is no Citrus Scab, because the temperatures there are too high for infection (mean 27° C.). On the other hand, at Los Angeles (California), Mobile (Alabama), and Nagasaki (Japan) Scab is prevalent, because at these places the mean temperature lies between 16° and 19° C., a range that is the optimum for both infection and progress of the disease.

Opinions vary as to the set of conditions necessary for the development of Black or Stem Rust of Wheat, *Puccinia graminis.* Apart from the survival of the uredospores, which has already been referred to, Bolley as

well as Freeman and Johnson consider that cool weather is necessary for its development, while Cotton, Levine, Stakman and Lambert and Walster consider warm weather as conducive to the occurrence of this rust. Stakman and Levine give 19°-21° C. as most favourable for vigorous infection. Heald agrees with this and considers that the low temperatures of 1904, in some States of the U.S.A., were responsible for the outbreak of the Black Rust in that year, such low temperatures retarding the crop and giving a chance for the development of increased numbers of uredospores. Peltier states that infection takes place under conditions unfavourable for the development of the disease, the optimum temperature being 20° C. for one strain tried and 25° C. for another. Infection also depends upon the stage at which the host has arrived; for, at the heading stage, infection takes place at a lower temperature than at other stages. Johnson recorded the germination of Stem Rust uredospores as being best between 9° C. and 25° C., the optimum as indicated by the vigour of the germ-tube, being from 12° C. to 17° C. Quite recently Lambert has examined the weather relations to Stem Rust of Wheat by the historical method; and, although he considers that warm weather in the growing season (May to July) is correlated with destructive epidemics, he nevertheless concludes that there is no evidence of any specific meteorological condition, or set of conditions, that always accompanies epidemics in the spring wheat areas of the U.S.A.

As to Yellow Rust of Wheat (*Puccinia glumarum*) Humphrey has stated that low temperatures are conducive to effective infection by this rust fungus. But it is peculiar that its uredospores, which are usually favoured by low and killed by high temperatures, should be able to germinate at 30°-35° C. More recently Mehta has tested the viability of the uredospores of Yellow Rust at high temperatures, and finds that for India, such spores have no chance of surviving the scorching heat of the summer months in the Indo-Gangetic Plain, where the shade temperature in several localities may occasionally reach 47° C. Mehta found that fresh uredospores of *P. glumarum*, collected in March and having then a 50 per cent. germination, suffered a gradual decline in germinating power from 40 per cent. at 30° C. to hardly 2 per cent. at 47° C. after three hours' exposure. After eighteen hours' exposure to 42° C., all viability was lost. Control uredospores, kept for eighteen hours at 28° C., showed over 30 per cent. germination.

The Leaf Spot of Tomato, caused by *Septoria Lycopersici*, is a well-known example of a warm weather disease. Pritchard and Porte were able to correlate high temperatures with its distribution. It is absent on the Pacific coast of North America and present only sparingly in the North Atlantic and Gulf States; but it is serious further south, in the Mid-Atlantic and Mid-Western States. This is occasioned by the limited range of temperatures favourable to spore production, namely 15°-26° C., with an optimum at 25° C. The fungus itself also grows over a range of 12° to 28° C. and best at 25° C. The kind of host growth that is particularly susceptible to infection, viz., long, succulent shoots, is produced at higher temperatures (25° to 30° C.) than those at which the maximum yield of fruit and a resistant type of shoot growth are produced. The existence of these two temperature ranges, namely 12°-28° C. for the fungus, and 25°-30° C. for the host should theoretically induce the development of disease where they overlap, that is from 25° to 28° C. Actually this is the optimum range of temperature found by Pritchard and Porte for the maximum production of the disease.

It was mentioned previously that the Potato Blight starts only at relatively cool temperatures. But after the disease has once made a start, warm weather is necessary for the development of an epidemic. On the other hand, really hot weather is inhibitive, and Blight is usually absent

from localities where the mean temperature exceeds 25° C. Smith considers that temperatures below 21° to 23·5° C. are most favourable for the spread of this disease, and his contention is rather supported by the growth-temperatures of the fungus in pure culture, which Jones gives as being optimum at 16°-19° C. Smith considered that a single hot, dry season may destory the fungus so effectively, that several successive wet, cool years are needed to re-establish it. Spore production is checked at 25° C. and the mycelium is killed, even in the potato tubers, at temperatures of 30°-35° C. In spite of this, however, Johnson stated that the disease progressed very slowly below 25° C. and was most active at from 25°-32° C., coming to a stop only at temperatures above 36° C.

Air temperature affects the progress of disease chiefly by influencing (1) the rate of growth of the fungus in the tissues of the host plant, and (2) the production of spores. With regard to the first of these, the rate of growth may affect the incubation period directly. Peltier states that at low temperatures *Puccinia graminis* lies dormant in the tissues after infection, and the incubation period may extend over seven to nine weeks. Stakman noticed that uredospores of this fungus appeared in five to seven days after infection at 19°-21° C., but that they appeared one day later for every 10° F. (5⅝° C.), rise above, and for every 5° F. (2⅞° C.) fall below, this optimum. Mehta examined the influence of temperature on the length of the incubation period in various rusts in 1921 and 1922. He consistently obtained longer incubation periods with lower temperatures. For example, in one experiment plants gave pustules on the thirteenth day at 16°-21 C.; but corresponding plants in the open, at a mean temperature of 1° C., did not give pustules till the thirty-sixth day. Mehta considers it probable that the mycelium does not lie wholly dormant but grows "by fits and starts" according to the variation of the external conditions. While such observations indicate that the mycelium of *Puccinia glumarum* and that of *P. triticina* may thus be able to overwinter as an extended "incubation period" yet experiments have aslo indicated that *P. graminis* cannot do so unless the temperatures are very mild. Mehta also found that the incubation period is extended by higher temperatures. Yellow Rust developed in eighteen days at the higher temperatures of August, but in nine days in June.

Fromme has also noted this relation of temperature to the incubation period with *Puccinia Coronifera,* having observed a decrease of five days when the temperatures reached 20°-30° C. Hart found that higher temperatures diminished the incubation period, but he also found that very high temperatures extended it with *Melampsora Lini* on Flax. At 7°-14° C. pustules appeared in fourteen days; at 16°-22° C. in ten days while at 25°-30° C. fifteen days were required. Melhus has noted that temperature affects the mycelium of *Phytophthora infestans*, infection becoming visible in two to three days at 23°-27° C., but taking longer at lower temperatures. Keitt found that visible infection of the Apple by Scab (*Venturia inaequalis*) took seventeen days at 8° C. but only eight days at 20° C. Melhus, while investigating the problem of the origin of epidemics arising from the planting of infected tubers, found that the extension of the Potato Blight fungus from the tubers into the growing shoots was favoured by a relatively high temperature (22° C.) but that it was inhibited by low temperatures from about 4°-6° C. Since it is still to some extent problematical as to how epidemics of Potato Blight really originate, this point is of interest, since it would indicate that if epidemics start from shoots infected with mycelium derived from infected tubers, the incidence of warm weather would facilitate the primary appearance of the fungus, while cold weather would check it.

Another relation of air temperature to disease may be mentioned, and that is the effect on sporulation. Conidia of the parasite seem to be produced, as a rule, at temperatures optimum for the existence of the disease. For example, Tisdale and Beach state that the conidia of *Phytophthora Nicotianae* and of *P. Cactorum* are formed at 20°-35° C. and a little below 20° C., respectively, at which temperatures the diseases they produce are at a maximum. That temperature, more than moisture, affects the production of the conidia of *Pseudoperonospora Humuli* on the Hop is indicated by Salmon and Ware, since they state that in spite of the dryness of the atmosphere during the hot weather of 1923, conidia were found on hop foliage. Again, Walker found that the conidia of *Colletotrichum circinans* (Onion Smudge) were produced at temperatures of 20°-28° C. in appreciable quantities, and these temperatures cover the optimum for the disease (23°-28° C.). Fawcett found that the conidia of *Cladosporium Citri* produced abundantly only at those temperatures near the optimum for the disease (16°-23° C.), namely at 21°-24·5° C.

The relation of temperature to plant disease may next be considered as it affects diseases contracted from the soil. This is much better known, since there are not so many variable factors to consider as with aerial diseases. There is practically no wind factor to consider, and the soil is slower to gain or lose heat than the air. Also, according to the moisture content of the soil, heat conservation varies, since water is even slower to gain or lose heat than soil itself. Soil temperatures are more stable than atmospheric ones, and can reasonably be expected to remain near a mean for a twenty-four hour period, thus rendering the meteorological data more reliable for use in phenological work.

One of the principal effects of soil temperature is upon the germination of spores, influencing as it does, both the percentage and the rate of germination. In regard to the rate of germination, Gilman found that the spores of *Fusarium conglutinans* (Cabbage Yellows) germinated in three hours at 33° C., in eight hours at 21° C., in twelve hours at 16° C., but not even in seventy-two hours at 8°-12° C. Shapovalov, with *Actinomyces scabies* (Common Scab) on the potato, found that the spores germinated in five hours at 30° C., in eight hours at 25° C., in eleven hours at 20° C., and in eighteen hours at 15° C., but required two days at 10° C.

A most noticeable cool weather disease is Powdery Scab of the Potato, caused by *Spongospora subterranea*. It was particularly severe in England in 1920, and that year was cold and wet; but it was almost absent in the hot, dry season of 1921. Heald states that in the cooler northern states on the Canadian border favourable conditions are provided for the disease, but that infected tubers planted in the warmer states (Massachusetts and Florida) yield absolutely clean crops. Ramsey states that in Maine (U.S.A.) the exceptionally hot and dry year of 1916 was very unfavourable for Powdery Scab. Experimentally he obtained 83 per cent. of Scab at 14° C., but none at 17·2° and 24·5° C. As far back as 1908, Massee recorded that the parasite passed from the amoeboid state into the active plasmodial state most markedly at 16° 19° C. On the other hand, while cool weather is favourable, really cold weather is inhibitive to the parasite, a temperature of 10° C. checking its active state and one of 0° C. resulting in its encystment.

Wart Disease of the Potato, caused by *Synchytrium endobioticum*, is favoured by cool weather and it was prevalent in England during the cool year of 1920, but relatively dormant in the dry, hot year of 1921. It has been stated that infection does not occur above 22° C. but it has been shown by Esmarch and Weiss that infection may occur at 30° C. Esmarch found the optimum range for infection to be 15°-20° C.; and since these temperatures existed in the soil from July to September, they explained the

maximum incidence of Wart Disease during that period. At these temperatures, too, the fungus itself is most active; and while infection does occur at both lower and higher temperatures, it is scanty and retarded, corresponding with retarded zoospore emission from the sporangium. Weiss obtained infection of tubers when resting sporangia germinated between 10° and 28° C. and when summer sporangia germinated between 0·6° and 30° C. He also found the maximum production of disease to occur between 15° and 20° C.

The fungus that usually causes the Sleepy Disease of the Tomato in Britain (*Verticillium albo-atrum*) is associated with cool weather conditions, and for this reason is not serious in the United States. In England, it is at times serious in tomato houses. It appears in April and continues to the second week in May, but then disappears till September. This is because of the inhibitive higher temperatures of June to August. Bewley found that by keeping the plants at temperatures above 24° C. they were prevented from wilting; and above 25° C. the fungus could not infect. At 12·5° C. the fungus grows very slowly up to the tomato stems, so that by keeping the plants a little below this temperature they escape infection. The minimum, optimum and maximum temperatures for the fungus in pure culture are 4·4°, 23·3° and 30° C., respectively, and those of the disease are 12°, 21·1° to 22·8°, and 25° C. As the plants thrive best at temperatures between 24° and 29·5° C. it is probable that the fungus is unable to cause infection, owing to resistance developed by the plant above 24° C.

Onion Smut, caused by *Urocystis Cepulae,* is epidemic in parts of the northern States of the U.S.A. but is absent in the southern states. Walker and Jones found that climatic differences accounted for this, the north being cool and the south warm. Onion seedlings appear above ground most rapidly at temperatures of 27°-29° C., but infection does not occur after a certain stage in the host's growth has been reached. This stage is when the cotyledon has reached from 2½ to 3 inches in height. Since increased temperature promotes rapid growth the susceptible period will be shorter at a higher temperature than at a low one. But temperature also affects the germination of the chlamydospores of this fungus. Walker and Wellman found that these spores germinated at temperatures between 9° C. and 32° C., with a maximim germination at 15° C. The same workers obtained maximum growth of the fungus between 18° C. and 22° C., but none at 9° C. or at 28° C. It is significant that infection occurs at temperatures, of from 10° C. to 29° C., being maximum at 19° to 24° C. Walker and Wellman conclude that while infection occurs at low temperatures it is not increased appreciably by higher temperatures. Attack, however, is more rapid and is correlated with better host and fungus growth. Above 25° C. the fungus is retarded, while the host is stimulated, so that the susceptible period is rapidly passed.

A large amount of work has been done on the important disease of Wheat known as Bunt and caused by *Tilletia caries*. The spores of this fungus germinate in the soil when conditions are suitable; and provided the wheat seedling has not passed a certain stage, infection results. The spores germinate at temperatures as low as 5° C. and as high as 25° C., the maximum germination being at 16° to 18° C. Woolman and Humphrey in America found a more extended range of temperatures for germination of Bunt spores, namely Min. 0°-1°, Opt. 18°-20°, and Max. 25°-29·1° C., but these are probably extreme, as the result of some unusual factor operating in the experiments of these particular workers. Hahne, in 1925, gave the following temperatures:—Min. 4°, Opt. 18° to 20°, and Max. 36° C. Still later results by Rabien, however, confirm Heusser's figures. The minimum, optimum and maximum for spore germination according to Rabien are:—5°, 16° to 18°, and 20° to 21° C., but

the maximum was extended to 25° C. by the addition of an oxidising agent to the germination medium. The special feature regarding infection is that wheat will germinate at lower temperatures than Bunt spores will. Where this is climatically possible, the solution to the problem of escaping infection is to show at times when temperatures are very low. Heusser found that wheat grain germinated at 3°-4·5° C. but the Bunt spores did not. Munerati also obtained no infection at 2°-4° C. for the same reason. Gibs on the other hand, obtained infection at 4° C.; but since the majority of workers have not obtained infection below 5° C., this result cannot be taken too seriously. Munerati found that grain that had germinated and grown at 2°-4° C. was immune from infection, but that this temperature had to be maintained for five weeks to enable the wheat to pass through the susceptible stage unharmed. Grain grown for only twenty days at 2°-4° C. became infected when subjected to a temperature of 10°-12° C. for a further seven-day period. It is strange that Rabien obtained no infection when he kept seeds continuously at 10° C. It might be supposed that the wheat could not germinate quickly enough at that temperature to pass the susceptible stage, and that is the only explanation. This is supported by his further statement that two lots of grain kept at 10° C. for three to five days and then transferred to 20° to 22° C., developed 0·7 per cent. and 6·3 per cent. of Bunt respectively; seed kept at 19° C. for eight days and then raised to 20°-22° C. gave 40 per cent. of Bunt. Also, grain kept at 5° C. for nine days, developed only a trace of Bunt; but after a longer period, the percentage rose to 49·1. This seems to show that wheat does not grow quickly enough to reach its resistant state, but that at low temperatures the Bunt spores germinate so slowly that they require a long time to infect. Further figures given by Heusser for the host growth seem to support this; the minimum, optimum and maximum for host growth are:—3°-4·5°, 25° and 30° C. Laufert found that in South Russia wheat sown in August comes up in three to four days, *i.e.*, too quickly for infection to occur, as the spores do not germinate rapidly enough. In Germany, however, temperatures are moderate (6°-10°C.), so that the spores and grain germinate together and infection is the result. This, of course, is contrary to Rabien's results at 10° C.

So much for the minimum temperature for infection. For optimum infection, Hungerford and Gibs give 9°-12° C. and Gibs states that at 17° C. wheat, although susceptible, grows so quickly that the spores, themselves most active, cannot infect. Faris states that the rate of wheat growth does not affect infection, since he obtained the greatest infection with plants that emerge first. As to the upper extreme, Woolman and Humphrey state that infection from seed-borne spores does not take place when seed is sown at or above 20° C., but that infection from spores in the soil is still possible. This indicates that these authors considered that spores took too long to germinate, when brought into favourable conditions at the same time as the wheat grains, to cause infection; but that spores, already in the soil with the right conditions, had germinated and were ready to infect when the wheat was sown. Butler states that in India Bunt occurs in the North-West Provinces because the temperatures at sowing time are usually below 25° C., permitting both spore and grain to germinate. But it is absent in the east and south, where the relevant temperatures are above 25° C. at the time of sowing and do not permit spore germination. Munerati found that wheat sown in seed-beds kept at 22°-25° C. for five weeks did not become infected. Grain sown and grown at 2° 4° C. for twenty days and then allowed to grow for a further seven days at 10°-12° C. became infected; but if this seven-day period was passed at 22°-25° C., infection did not occur. Hungerford found that infection in controlled experiments resulted at temperatures up to 25°-28° C., but at this limit it

was almost negligible. In America, farmers are said to escape Bunt in the Pacfic North-West by sowing their wheat either very early (warm, above 22° C.) or very late (cold, below 5° C.)

As an example of a hot weather disease the ordinary Scab of Potato, caused by *Actinomyces scabies*, may be taken, which was very prevalent in England during the hot, dry year of 1921. There are indications, however, that warm, rather than hot, years are most favourable, for Jones *et al.* state that the optimum temperature for Scab development is about 22° C., although in some trials it was 25° C. Further, the optimum temperature varied with the type of infection; for the highest percentage of scabbed tubers it was 23° C. but for the highest percentage of total tuber surface scabbed it was 20·5° C. These workers at Wisconsin also found that at 11° and at 30·5° C. scab was very slight. They had previously shown that the number of infections remains as large, above the optimum temperature, as at that point, but that since tuber growth was inhibited, the average size of the Scab lesions was reduced. Sanford originally indicated a wider range for maximum infection, viz., from 14° to 22° C., but later he found that, although no Scab usually occurred in the field below 12° C., yet it was not greatly influenced by temperatures between 12° and 25° C. Jones *et al.* state that Scab is worse with more rapidly-growing tubers and that the effect of temperature on Scab is indirect, *i.e.*, through its effect on the host. Sanford, in stating that best tuber development occurred at 18° to 21° C., confirms this, since Scab is certainly most pronounced at about 20° C. Although this host relation is stressed by Sanford and Jones, it is significant that a report on this disease from Ohio gives temperatures for the growth of the organism which almost coincide with those most conducive to Scab. Growth was very slow below 50° F. (10° C.), was maximum at 65°-75° F. (18-24° C.) and reduced to nil at 80° F. (26·6° C.). Compared with the Scab temperatures as given by Jones *et al.*, namely, 11° C., 20°-23° C., and 30·5° C. the agreement is fairly close.

The Smuts of Sorghum, caused by *Sphacelotheca Sorghi* and *S. cruenta*, are also warm weather diseases, and Kulkarni has shown that the times of sowing and the districts where Sorghum is grown in India determine the prevalence of these diseases. The monsoon crop, sown in June and July, experiences an average temperature of 21°-27° C., which fulfils the optimum infection condition; while the winter crop, sown in September and October and experiencing a temperature of 32°-38° C., becomes much less infected. The scarcity of these Smuts in the Indo-Gangetic plain is explained on this basis, the temperatures there at sowing time being about 32°-38° C. Sorghum germinates most rapidly at high temperatures, taking one and a half days to do so at 37° C.; at lower temperatures it germinates slowly, taking three to four days at 20°-23° C. The spores of these Smuts germinate most abundantly (90 per cent.) at 20°-23° C., but only 1-2 per cent. germinate at 37° C. Infection succeeds at temperatures between 16° and 30° C. Kulkarni tested these observations by pot experiments. Seeds incubated at 40° C. for three days produced no Smut, but seeds incubated three days at 25° C. gave various amounts of Smut. In experimental plots distributed between four experiment stations, infections resulted only in those plots in which the temperatures at sowing time were below 36° C. At Jacobabad, with a temperature range of 36°-40° C. at the sowing period, no Smut was obtained. Reed and Faris obtained similar results. These Smuts are warm weather diseases, since, although the greatest degree of infection does not occur at the highest temperatures, yet the range of temperature for heavy infection reaches a fairly high level. Again, whether the conditions of infection may be called warm or cool

depends upon the locality. In India, Kulkarni calls weather favourable to infection "cool," but compared with a climate such as that of England, a temperature of 30° C. would not be called cool.

MOISTURE

That the incidence of plant diseases is correlated with the occurrence of wet and dry years had been recognised for a long time before it was realised that this apparent relation could not easily be separated from temperature relations. For example, Potato Blight was practically absent in this country in the dry year of 1919; but was this due more to the absence of rain than to the extreme heat of the weather experienced ? It is impossible to answer that question off-hand. The weather relations of this one disease alone are too complicated to permit of its incidence being explained on the basis of a single factor. Where it occurred, *Pseudoperonospora Humuli* on the Hop was serious in the wet seasons of 1922 and 1924, but practically negligible in the dry seasons of 1921 and 1923 *Puccinia glumarum* was absent in Cambridgeshire in 1921 also.* But unless the moisture relations of those and other diseases are studied over a much longer period of years, or over a wider range of climates, in order to obtain data as to whether they also appear in hot wet years and in cool wet years, and thus eliminate temperature effect, it is impossible to correlate moisture with disease incidence. On the other hand, it is now possible to carry out experimentally controlled moisture-relation tests, in which other factors, such as temperature, are kept constant. In this way, it has been possible to correlate definitely certain diseases with dry conditions and others with wet conditions. Of these, those occurring in the soil, *i.e.*, in the underground parts of the plants, are by far the most easily studied. Diseases of the sub-aerial parts, such as the cereal Rusts and Potato Blight, are as yet but imperfectly understood as regards water relations.

As was shown with temperature, moisture has a relation to the overwintering of the spores of fungi. Since more is known regarding this relation in respect of soil fungi, these will be considered first. Some data are available concerning the overwintering of cereal Smut spores. Woolman and Humphrey found that Bunt spores (*Tilletia caries*) overwinter successfully when still aggregated in the form of "butts." As separated spores, however, they lose their viability in one to two months in damp soil. When kept dry for twelve years they have remained viable. Hungerford also regards two to three months as the limit of viability for Bunt spores in damp soil, but he does not put a limit when they remain aggregated. He tested the length of life of Bunt spores in soils having different moisture content, the spores being sown in wet and dry soil, respectively. One series was maintained wet throughout the whole period of the experiment, while the other was moistened only at the time of sowing the spores. Wheat grains were sown at intervals of a few days each. The viability of the spores was measured by the resulting percentage of smutted plants. Grain sown along with Bunt spores in wet soil gave 30-35 per cent. smutted plants. Grain sown one month after the addition of Bunt spores gave 2 per cent. smutted plants, where the soil was kept continuously moist during the month that elapsed after the addition of the Bunt spores and the sowing of the wheat. But wheat sown one month after the addition of Bunt spores to soil that received no further water after the first day, developed no Bunt. Lastly, wheat sown along with Bunt spores in dry soil gave 19-23 per cent. smutted plants; but

* At the Cambridge University Farm, *P. glumarum* is very late in appearing this (1929) season. It did not appear until June 4th, and had advanced very little by June 21st. This is attributed by Professor Biffen to the prolonged spell of dry weather which has been experienced since the beginning of this year.

sown one month subsequent to the spores, in soil kept continuously dry, it gave only 3-4½ per cent. smutted plants. This indicates that under normal winter conditions, Bunt spores present in the soil from a previous season would not remain viable till the following spring, but would infect grain sown in the autumn. On the other hand, according to Griffiths, the spores of Flag Smut of Wheat (*Urocystis Tritici*) can overwinter in the soil, even when previously watered.

Soil moisture also has a very direct influence on the evacuation of the resting sporangia of the potato Wart Disease fungus, *Synchytrium endobioticum*. Esmarch states that evacuation is impeded by dry conditions, but greatly favoured by wet seasons. There are more empty sporangia in spring and summer than in autumn and winter. He also states that oxygen is necessary for this evacuation. Since excessive moisture would bring the oxygen content of the soil down to a minimum, it would be expected that these conditions would inhibit evacuation of the sporangia, but Esmarch does not bring evidence to support any such conclusion. Miss Glynne's experiments also support Esmarch's results, as infection was not obtained in dry soil, while various degrees of infection were obtained in wet soil. The swarm-spores of this fungus, of course, require water in which to swim in order to reach the place of infection. Should the soil dry out before infection has taken place, the swarm-spores die.

As to the connection between moisture and oxygen supply, two good examples can be given. With ordinary Scab of Potato, caused by *Actinomyces scabies*, soil water is necessary only in very small quantities, the disease being a dry soil one. A so-called dry soil usually has just enough moisture to allow spore germination and activity of the pathogen; but wet, or at any rate, excessively wet soil as contrasted with merely moist soil, is very inhibitive to this pathogen. Sanford has shown that this is because oxygen is necessary for germination of the spores. The same relation has been found with the Loose Smut of Oats, *Ustilago Avenae*. Miss Jones found that as the soil moisture increased, especially from 60 per cent. to 80 per cent. of the water-holding capacity of the soil, the percentage germination of the spores of this Smut proportionately decreased. In the complete absence of oxygen, germination did not occur, thus confirming the moisture-oxygen relation.

With the Powdery Scab of Potato (*Spongospora subterranea*), all agree that the disease is severe in wet seasons only. Ayoutantis states that, in Algeria, this disease occurred as an epidemic in 1922, when an unusually heavy rainfall gave the necessary conditions for its development. Normally, the conditions in Algeria are too dry for this Scab to appear. Ramsey checked his field observations by controlled glass-house experiments, growing potatoes in pots kept dry, moist and wet, respectively. He obtained no Scab in the dry pots, but 83 per cent. of Scab in the two other series. Even if the low moisture content of the dry soil is sufficient for spore germination, it is evidently not sufficient for infection. That Powdery Scab occurs in soils kept very wet is explainable only on the supposition that oxygen has no influence on spore germination or infection. Infection of potatoes with Wart Disease occurs only with a high soil-water content. But whereas germination of the resting-sporangia does not take place unless the soil is saturated at some time, infection is repressed if the soil is kept constantly saturated. Weiss considers periodic flooding and drying most suitable for infection. That a saturated soil is best, at some period at least is explained by the fact that the swarm-spores need water to migrate through the soil to the new crop of tubers.

With *Ophiobolus graminis*, causing Take-All of Wheat, a similar relation of high soil moisture to infection holds goods. Here, however, the interacting factors are better known. This disease has been reported

by some as serious in dry seasons, by others in wet seasons; but as McKinney and Davis pointed out, these reports dealt with the after-effects of certain types of weather upon the host plant, and not upon the actual infection process. Wet weather, by causing the plant to develop new roots, defeats the ravages of the fungus from a practical point of view; but the inability of the plant to produce roots in dry weather merely allows the fungus an equal chance of root destruction. The dry weather, which proved fatal to the plants, followed a period of wet weather that had favoured infection. In their experimental work McKinney and Davis obtained less infection at low moisture content than at high; but whereas the difference was large at high temperatures, it was small at low ones. This indicates that a certain quantity of moisture, which may be considerably below that required for infection, is necessary for the expulsion of the spores of this fungus from its perithecia, or for the germination of spores when liberated.

The disease most widely known as a dry soil disease is the ordinary Scab of the Potato, (*Actinomyces scabies*). Martin, in America, gives data covering three years in which the rainfall varied considerably, and during which varying amounts of Scab resulted. While the temperature was approximately the same for the three years 1920 to 1922, rainfall was lowest in 1921, and for the period June and July was almost half that in the same periods in 1920 and 1922. Correlated with this was almost 100 per cent. of Scab in 1921 and 76 per cent. of Scab in the wettest season of 1920. In control experiments Martin reduced the surface scabbing from 41 per cent., at 30 per cent. soil moisture content, to 2·6 per cent. Scab at 60 per cent. Sanford's results, while in agreement with those of Martin, showed that moisture was of influence during the early stages of growth only. If, during this period, the tubers are kept under nearly saturated conditions they do not become infected, even if the soil becomes dry afterwards. Probably there is enough water present in dry soil to allow growth of the organism and infection; but with high soil moisture content the tuber must be affected in such a way that infection becomes impossible, because much moisture is favourable to the growth of the parasite. It has been stated that the most abundant development of Scab was obtained in light "well-drained," alakaline soil, with a "good supply of moisture." Under such apparently contradictory conditions it is difficult to conclude definitely what may be the decisive factor inducing the disease apart perhaps from the *p*H value of the soil. At low soil moisture content, growth of the organism is reduced, infection is at a maximum, and the plant not very susceptible. At medium moisture content, both plant and organism grow normally and infection is reduced; while at high moisture content infection is inhibited but the plant made most susceptible. This last condition seems to point to the fact that the fungus is inhibited also, since the plant is susceptible, and plant growth is reduced at low moisture content only because of lack of water. It is rather remarkable that both oxygen content and infection are maximum at low moisture content, while the former is at a minimum, and the later inhibited at high moisture content. It thus seems that moisture relations are important only in so far as oxygen supply is affected.

It is commonly stated that if Bunt is to be avoided it is better to sow wheat in a dry seed-bed than after rain. In confirmation of this Hungerford and Wade obtained only a small amount of Bunt in fields sown under dry conditions, but in fields sown soon after rain, 30 per cent. of Bunt appeared. A contrary statement is made by McAlpine concerning Flag Smut of Wheat, caused by *Urocystis Tritici*. He states that far more infection results if wheat is sown in dry soil than if it is sown subsequent to rain.

These cases may be analysed and thus further light thrown on the problem. There are four different effects when wheat grains and Bunt spores are sown in a dry seed-bed. Firstly, the dryness may prevent both spores and grain from germinating; secondly, it may allow the spores to germinate and not the grain; thirdly, it may allow the grain to germinate and not the spores; lastly, it may allow both to germinate. The last may at once be dismissed since infection would result, and this does not happen in dry soil if no rain occurs. With Flag Smut of Wheat, McAlpine considers that the first relation holds, both grain and spores germinating only when rain comes. He obtained 14 per cent. Smut in dry soil. He placed Bunt in the second category, as he considered that the spores germinated in dry soil but not the grain, the latter doing so when rain came, by which time the spores had germinated and had died. Kulkarni places the Smuts of Sorghum (*Sphacelotheca sorghi* and *S. creunta*) in the second category for the same reason. Many other workers, however, place Bunt in the third category, the grain germinating in dry soil and passing through the susceptible stage before rain occurs enabling the spores to germinate. Mackie states that Bunt spores need 14 per cent. soil moisture in order to germinate. That Bunt spores should germinate in dry soil is not in good consonance with the fact that such spores may remain viable in the soil for years. It is much more natural that they should not germinate in dry soil, and that Mackie's statement that 14 per cent. moisture is needed is correct. Provided that the host plant has germinated, and is still in the susceptible stage, and that the spores are able to infect, the question is whether there is any relation between the degree of infection and the amount of water present, above the minimum.

It has been found that there are two types of correlation; first, infection increases with increase of moisture, and second, infection decreases with increase of moisture. Bunt of Wheat and the Smuts of Sorghum belong to the first type. With the latter Kulkarni found that below 5 per cent. of moisture, infection did not occur, but it started with 7·5 per cent. of moisture, and increased in proportion with the increase of moisture up to 20 per cent. Hungerford and Wade did not obtain any Bunt below 15 per cent. of moisture, but it increased from 7 per cent. at 15 per cent. of moisture to 62 per cent. at 36 per cent. in one series, and from 25 per cent. at 17 per cent. of moisture to 100 per cent. at 38 per cent. in another series of experiments. Hungerford, in a later paper on combined temperature and moisture relations of this fungus, found that at low temperatures Bunt increased with increase of moisture, but that at higher temperatures it decreased with the increase of moisture. Since temperatures are rarely so high as 17° to 25° C. at the time of sowing wheat, however, one may practically say that an increase of moisture increases the percentage of Bunt. Faris also found that increase of moisture increased the attack of Bunt, although he used spores of *Tilletia levis*. It is of interest, though, that Rabien as recently as 1927, recorded some experiments on the adverse influence of high moisture on Bunt incidence. Wheat in dry soil gave 22·3 per cent. of Bunt, that in normally moist soil gave 55·3 per cent., while that in very moist soil gave only 10·7 per cent. Rabien attributes the reduction of Bunt at very high moisture content both to the rapid germination of the wheat grains and to the retardation of spore germination by the consequent reduction of the oxygen supply. Gibs' observations support the contention that Bunt should be placed in the second type referred to above.

In spite of Hungerford's conclusions regarding these relations, he records two experiments, amongst many others, in which the data support Gibs and Rabien. At the most favourable temperatures of 9°-12° C., which, it must be noted, are "low," he obtained a reduction from a high

infection of 90 per cent. at 22 per cent. moisture to a low infection of 19 per cent. at the higher moisture content of 32 per cent. At the still favourable temperatures of 17°-25° C., a reduction from 21 per cent. infection at 18 per cent. moisture to no infection at 32 per cent. moisture took place. With other fungi of the same class, similar results have been recorded by many workers. Reed and Faris and Kulkarni obtained higher infections at lower moistures with *Sphacelotheca Sorghi* and *S. cruenta*. Christensen found the same with *Sorosporium reilianum*, the cause of Head Smut of Sorghum. Bartholomew and Jones, and Reed and Faris obtained higher infection at low moisture with Loose Smut of Oats.

There is a further relation between soil moisture and the progress and intensity of a disease. This is not always separable from the infection relation, and has not received so much attention. A few examples may be given. Soil moisture affects the length of the incubation period. This is rarely examined, as it is very difficult to determine when the first signs of disease appear in the case of soil diseases. Clayton found that the incubation period of Tomato Wilt caused by *Fusarium Lycopersici*, varies according to both temperature and moisture. Here it suffices to state that with 14 per cent. of moisture the period was thirty-five days, with 18 per cent. moisture it was twenty-six days and with 24-32 per cent. moisture only nineteen to twenty days. This is probably because the greater amount of moisture provides more ideal conditions for the growth of the fungus, and it agrees well with the statement that the most vigorous plants are most attacked.

Moisture can influence the optimum production of disease by reacting on the host. In Crown Gall, caused by *Pseudomonas tumaefaciens*, Riker states that the largest galls are produced at 60 per cent. moisture, and their formation is partly correlated with the best plant growth (at 80 per cent. moisture). With *Plasmodiophora Brassicae*, which causes Clubroot of Crucifers, Monteith found the largest malformations associated with the largest and most vigorous plants, both induced by high moisture. He also found that old and non-vigorous plants were not attacked. These two cases can be explained by the reaction of the host cells to the supply of moisture. In spite of stimulation due to the presence of the respective parasites, the cells could not make abnormal growth if the moisture supply was limited, but they could do so when this was normal.

Another instance of the influence of moisture upon the intensity of a disease is afforded by Cabbage Yellows, caused by *Fusarium conglutinans*. Tisdale found that this disease develops most rapidly at lower moistures (19 per cent.), falling off at 26-28 per cent. moisture; he also found that the host plants grew best at 19 per cent. of moisture and less at higher moistures. Tims noted that vigorous plants are most subject to the disease, and states that plants grown under poor conditions, such as low light intensity and low moisture, will remain for weeks with a low percentage of disease, growing slowly and with thickened tissues. Resistant plants which, under normal moisture conditions carry on as if uninfected, are often in fact infected; but the fungus is unable to prevail in vigorous plants of a resistant strain. If the moisture content is lowered, however, the plants lose their vigour and the fungus progresses up the plant at once and causes wilt. Such plants will recover if a supply of moisture, adequate for vigorous plant growth, again becomes available. The amount of soil moisture probably has some influence on aerial diseases. Howard states that wheat sown in pots under conditions of good soil aeration had much less Black Rust (*Puccinia graminis*) than those in the field with inadequate aeration. It is more likely that an effect of this kind as to do with atmospheric humidity in the midst of the crop; but this will be discussed in the next section.

Stakman grew wheat under low and high soil moisture conditions and obtained less infection with low soil moisture. Howard states that flax with deep and abundant roots, when grown in an alluvial soil with good moisture supply, was heavily attacked by *Melampsora Lini,* while flax with shallow roots was free from the rust. Evidently, the shallow roots were able to supply enough water for good growth, but not enough to supply the demands of the parasite or to make the tissues susceptible. This investigator found a similar result with sugar cane; this host was attacked by *Colletotrichum falcatum* on stiff, black soils (excess water), but was very free from the disease in open porous soils. Smith, in discussing the Rust of Asparagus (*Puccinia Asparagi*) in California, states that in dry soils, and in dry seasons, asparagus becomes infected by the uredospores of this fungus in the summer, and from the teleutospores in the autumn. In wet seasons, however, it becomes infected from the teleutospores only, in the autumn. He explains this by the adverse effect of the lack of soil moisture on the plant, which causes it to be more susceptible to the fungus. The latter obtains enough moisture in dry seasons to enable it to infect the host plant, but in wet seasons the fungus is not invigorated in proportion, although the host plant is greatly invigorated and succeeds in thwarting the attempts of the fungus to cause infection. The teleutospores appeared on the plants in the autumn because the plants had then matured and lost their vigour.

Another instance is afforded by the Wheat Mildew *Erysiphe graminis.* This is stated by Rivera, in Italy, to be particularly severe when the soil dries out, causing the wheat plant to become more susceptible by the resulting lessening of turgescence. The Mildew is particularly prevalent on plants in rich soils, where root development is relatively restricted, and they would naturally suffer from shortage of water or from excessive transpiration. Fromme and Murray state that soil moisture, as influenced by rainfall, governs the seriousness of the Angular Leaf Spot of Tobacco, caused by *Bacterium Angulatum.* With high soil moisture, the resistance of the plant becomes reduced and infection is increased in proportion.

ATMOSPHERIC HUMIDITY AND PRECIPITATION

These factors were for a long time neglected, but lately much study has been devoted to them. At the outset it must be realised that the effect of atmospheric humidity is largely bound up with other factors, such as temperature, light, wind, rainfall, crop density, clouds and the physical nature of the soil. The interaction of all these factors on the physiology and metabolism of the plant is too complex for discussion here, and the various explanations that have been given of the incidence of disease as influenced by atmospheric humidity cannot be dealt with in any detail. It must suffice for present purposes to call attention to the existence of relations between humidity and disease, and explanations must await the securing of more data.

Passing over the obvious ways in which atmospheric humidity or its absence may influence the hardness or softness of tissues, their turgescence, and so on, it can be shown that susceptibility to disease may be related to the effect of humidity on stomatal movement. Pool and McKay demonstrated this with the Leaf Spot of Beet, caused by *Cercospora beticola,* in which infection can take place only through the stomata. High humidity favours their opening, but low humidity favours closure, the degrees thus enabling infection or preventing it.

There is also some evidence that humidity affects the survival of fungus spores, such as certain conidia and some Rust spores. Hart for example, found that the uredospores of *Melampsora Lini* (Flax Rust) remain viable

longer at relative humidities of about 60 per cent. than at lower ones, and their viability is reduced at very high and very low humidities. Spaulding and Gravatt found that the sporidia of *Cronartium ribicola* require a moist atmosphere in order to remain viable long enough to cause infection, apart from their need of dew or rain for germination and infection. They survived for twenty-six hours at 70 per cent. humidity, but rapidly lost their viability in drier air.

The literature concerning the germination of fungus spores is far too voluminous to review here. All of the many kinds of spores need different degrees of humidity and water-films. The conidia of the Peronosporales, for example, are dependent upon the presence of actual water-films on the foliage, since the swarm spores are capable of causing infection only after a period of swimming in a water-film. Doran reviewed the literature of this problem in 1922. Patel showed that the conidia of *Peronospora Trifoliorum* would not germinate on dry slides in a saturated atmosphere, but did so in a film of water. Melhus showed that the same was true for those of *Phytophthora infestans*.

With regard to Rust spores, most investigators have found that uredospores germinate only in liquid water, and not in saturated air. Teleutospores such as those of *Cronartium ribicola* also need water; aecidiospores also, such as those of *Melampsora Lini*; further, sporidia, such as those of *Puccinia graminis* require water. Although Fromme states that very high humidity was necessary for the germination of the uredospores of *Puccinia coronifera*, he obtained only 6 per cent. infection as a result of 93 per cent. humidity, and this is quite at variance with Durrell's statement that the almost identical rust, *P. coronata*, depends on actual water for germination. Two other exceptional results in regard to germination are those of Smith, who obtained 54 per cent. germination with the uredospores of *Puccinia Sorghi* in moist air at 100 per cent. humidity, and those of Taubenhaus who obtained germination of the teleutospores of *Puccinia malvacearum* in moist air also.

There is also a correlation between precipitation and relative atmospheric humidity and the expulsion of spores from the fructifications of many fungi. The pycnospores of Endothia parasitica (the Chestnut Blight fungus) are stated by Heald and Gardner and by Studhalter and Heald to be ejected both during and after rain. Smilely showed that fungi, other than members of the Ascomycetes, discharge their pycnospores during rain, *e.g.*, *Phyllosticta Antirrhini*. Although ascospores are also discharged during rain, the conditions of the air very soon after the cessation of rain influences the continuance of the expulsion. For example, Heald and Walton found that the ascospores of *Endothia parasitica* are dependent not only on the soaking of the perithecia by rain for expulsion, but also on the relative humidity of the air when the rain stops. Unless the humidity remains very high, expulsion ceases, and it diminishes in proportion to the rate of fall of the relative humidity. The length of a period of dry conditions, too, influences the capability of perithecia discharge their ascospores, as for example in *Endothia parasitica*. With this fungus, Heald and Studhalter found that the longer the perithecia were exposed to desiccation, the less able they were to liberate their ascospores when favourable conditions of moisture returned. The longer this period of desiccation, the longer was the interval between the onset of favourable conditions and the resulting first expulsion. If this desiccation period were indefinitely prolonged, a point would ultimately be reached at which the return of favourable moisture conditions would no longer cause reaction. This follows because, on the average, the necessary length of period of conditions favourable for expulsion would be less than that required by the delay

caused by the extended desiccation period. The above writers state that this absolute inhibitive desiccation period is about three months. The desiccation does not affect the power of the spores to germinate, but merely influences their expulsion.

In the apple Scab fungus, *Venturia inaequalis,* the discharge of the ascospores from the perithecia depends upon rain. Keitt and Jones state that the presence of dew is not enough, but that the ejection of ascospores was always traced to the beginning of rainfall. They further state that it is impossible at present to be sure that the spores cannot germinate without liquid water, since the methods of experimentation under conditions of high humidity do not preclude the possibility of the presence of minute quantities of liquid water. Both Aderhold and Wiltshire stated that the germination of those spores did not take place in a saturated atmosphere.

Whether infection will take place or not also depends on how long moisture remains on foliage. Peltier and Frederich state that the Citrus Scab fungus, *Cladosporium Citri,* needs water on the foliage for a considerable time before infection takes place, infection being a matter of hours and not minutes. Keitt and Jones showed that the wetting of apple foliage, required for infection by *Venturia inaequalis*, must be extended and continuous, and the period varies with the temperature, viz., at 6° C., thirteen to eighteen hours; at 9° C., nine to eleven hours; at 15° C., eight and a half hours; at 20°-24° C., four to six hours; and at 26° C., eight to ten hours. Discontinuous wetting, nevertheless, seems to be an advantage, since the germ-tube in the dry period has an opportunity to adhere to the surface of the leaf by the formation of an appressorium. Hart states that for the infection of flax by *Melampsora Lini* abundant moisture is of no use if it does not remain for more than one and a half hours. On the other hand, a small amount of water is sufficient for slight infection, provided it lasts for three hours; but for the occurrence of severe infection, over twenty-four hours are needed. Tehon and Young observed that *Puccinia graminis* appeared on wheat more or less consistently whenever a certain amount of rain occurred from five to seven days prior to the first symptoms.

The period during which rain occurs also varies in its effects. Moreland found that in India the amount of rainfall at seeding time is not related to attack of cereals by Rust. Of records at three places, Rusts followed in seasons following wet Octobers in seven instances, but they followed dry Octobers in six other cases. He found, however, that rainfall in January and February was related to Rust infection, since it influenced the state of atmospheric humidity. High rainfall and cloudy weather were conducive to high humidity, and whenever this combination occurred Rust followed. Beauverie states that *Puccinia glumarum* is a Rust of early host growth combined with wetness; *P. graminis* a Rust of wet seasons but appearing late in the season, and *P. triticina* a Rust of dry years, tending to appear towards the latter part of the season. Later, he discussed the occurrence of a violent epidemic of *P. glumarum* in 1923 in Auvergne (France). That year was abnormally wet in the season (three inches of rain fell in April as against the normal two inches) but later became dry, about the time of ear formation. Early in that year the high rainfall and high temperature caused precocious growth, and this was the condition most suitable for attack by *P. glumarum*. His observations are supported by Foex, who, however, is reticent in drawing definite conclusions.

Concerning the humidity factor very definite indications have been obtained by Stoughton with the Angular Leaf-Spot disease of Cotton, caused by *Bacterium malvacerum*. Infection was only slight at the high

temperature of 32° C. with over 80 per cent. relative humidity, but with the same humidity at 24°-28° C. moderate to heavy infection resulted. Moreover, with a lower humidity of 70 per cent., even at the same favourable temperatures of 24°-28° C., infection did not occur. Here there is no doubt about the influence of humidity. Roussakov as well as Pool and McKay consider that rain in the open field helps to increase the humidity amongst the crop plants, this being higher than in a dry season when the soil dries out. But the former writer goes further and discusses the time of occurrence of the rain, stating that rain in the daytime does not conserve humidity but lowers it, therefore increasing the effect of rain during the night which does not lower humidity. Both he and Pool and McKay observe that the atmospheric humidity prevailing in the midst of the crop plants is different from that in the open air at about five feet above the crop. It varies not only in this way but also within the crop itself, usually being greater near the soil and decreasing with ascent above soil level. Similarly, the density of stand of the crop affects the humidity and thereby the intensity of disease. Butler noted that Yellow and Brown Rusts were severe in the middle of a wheat crop at Pusa, India, where the crop was dense, but there was no Rust on the borders of the same crop where the stand was much less dense. The humidity was 20 per cent. higher in the dense part of the crop than on its borders. This is in agreement with Moreland, who recorded bad Rust attacks in three years of over 80 per cent. humidity, some Rust in one year with 79·5 per cent. humidity (all four records being at Allahabad, India), but no Rust below 67 per cent. humidity at Jhansi.

It is peculiar that the Mildew *Erysiphe graminis* should be able to cause infection at relatively medium humidities, 75-80 per cent., as found by Fromme, but Butler states that the allied fungus, *Erysiphe Polygoni*, causing Pea Mildew, is more prevalent in India in dry years; it may be that these Powdery Mildews have a considerable power of adaptation to varying conditions. In any case, sufficient data are not at hand to correlate any one, or a series of conditions, with incidence of these Mildews. Rivera has put forward a theory concerning the alteration of conditions causing respectively turgescence and wilt. These he considers sufficient to explain the incidence of Powdery Mildews, but at present not enough data are available to establish his contention.

Butler has pointed out the relation of dew to several diseases, the most important of which is the Potato Blight. In India the disease is endemic only at from four to seven thousand feet above sea level, and it is normally absent from the plains. This is bound up with temperature conditions and the resulting deposition of dew. In 1912 "seed" was brought from these altitudes to the plains rather late, and as the temperature was unusually low, and fogs and dews also occurred in December, the result was a Blight epidemic in January, 1913. His observations are supported by those of Reed in America, who states that, in Virginia, Blight is absent below two thousand feet, but gets more and more severe the higher the crop lies above that height. This is because the more highly situated the crop the cooler the nights (and also the greater the difference between day and night temperatures), and therefore the more copious the deposition of dew. The Die-Back disease of Chillies (*Vermicularia Capsici*) in India, studied by Dastur, is also dependent upon dew, and Dastur states that the humidity necessary at the flowering time is above 80 per cent. Whenever the humidity falls below this point in September, the disease does not appear. As the season advances beyond November, the disease disappears, because the lowering of the day temperature prevents the deposition of dew at night. Massee suggested that whenever infection was proved to take place

only at night, this was because dew is deposited only at night. He tested this by tying healthy Marrow plant leaves in paper bags, six being left exposed and six protected in the bags during the day, while at night the conditions were reversed, those protected during the day being exposed during the night. Only those leaves exposed at night became infected by spores of *Sphaerotheca Humuli*. He suggested that in addition to the presence of film of moisture on the leaf at night, the cells of the leaf were fully distended with liquid (because of retarded transpiration) and contained more sugars then than during the day, thereby offering ideal conditions for infection.

LIGHT

Light, being essential to the normal metabolism of all green plants, must indirectly be connected with the occurrence of parasitic diseases. Any factors that tend to alter in any degree the normal light relations of a plant, must tend either to predispose the plant to attack by disease or to confer resistance. Two important ways in which light affects plants are in photosynthetic process, and in transpiration. Light may also be related directly to the disease producing organism. Most bacteria are killed by intense light and certain fungus spores may be killed by strong sunlight. Hart states that infection of flax by *Melampsora Lini* is independent of light but Stakman found some reduction of infection of wheat by *Puccinia graminis* with greater light intensity. Light has probably an important influence on the production of certain fungus fructifications. Hammarland states that light is essential for conidial production in several species of *Erysiphe*. Davis with *Ophiolobus graminis*, the Take-All disease of wheat, says that light favours perithecal formation, while Coons states that light is absolutely essential for pycnidial formation in *Plenodomus fuscomaculans*. Hart found that the pustules of *Melampsora Lini* on flax appeared most rapidly when light was continuous, but that the incubation period was lengthened by alternating light and darkness. In some cases light may increase the temperature of plants. Stevens has shown the temperature of plant tissues to be several degrees higher in sunlight than when shaded. Leaves shade stems to some degree, and stevens found that the temperature of certain Blackberry canes, shaded by leaves, was 27°-29° C., while that of the unshaded canes was 31°-35° C., the air temperature in the shade in the experiment being 26°-27° C. The stems of some plants, such as potatoes, are much more shaded than those of others, *e.g.*, blackberry canes, and this feature is of importance when using field data.

It is an interesting fact that alternating clear and clouded skies produce a higher temperature on exposed plant tissues than a continuously clear sky, the reflection from the clouds causing the difference. In connection with this shade factor, two or three diseases may be mentioned. With "Yellows" Shapovalov and Beecher found that tomatoes artificially shaded were less infected, that the incubation period was lengthened, and that the plants grew away from the disease even though previously infected, as compared with non-shaded plants. It was supposed that shading lowered the rate of transpiration. Trelease and Trelease, working with wheat mildew (*Erysiphe graminis*), found that intense light prevented the disease, while shading the plants allowed heavy infection to occur. This disease is rarely found in the open fields in the United States, and Butler states that in India the Mildew has been seen causing serious damage only in half-shaded plants. Trelease and Trelease ascribed the prevention of Mildew by strong sunlight to a direct inhibition of the fungus or to the greater evaporation and consequent drying of its conidia and mycelium. But they did not record any experiments in which direct sunlight was still allowed to fall on the leaves, under conditions where high humidity, in spite of

high temperature, was possible all the time. With Fusarium Wilt of the Potato (*F. oxysporum*), Haskell found that the disease was almost absent where the crop was shaded by an elm tree. Bewley notes that by shading tomato plants the temperature is lowered. But whereas the lower temperature is more favourable for the Wilt fungus (*Verticillium albo-atrum*), generally prevalent in English glasshouses, the host plant does not wilt because of lowered transpiration. It is also likely that Haskell's disease also entails reducing wilting rather than actual inbitition of the parasite.

There is a more definite relation between light and infection, and that is in connection with the deposition of dew. It is stated that certain diseases are prevented by shading off the heat rays of the sun, thus preventing dew deposition. The diseases in question are Asparagus Rust, Celery Blight (*Septoria Apii*), Ginseng Blight (*Alternaria Panax*), and Strawberry Leafspot (*Mycosphaerella Fragariae*)

WIND

There is no doubt whatever that wind is an agent of dissemination of both fungi and bacteria. After being liberated from their place of origin, spores and bacteria are carried up by air currents into the wind proper. The actual details of what happens to spores afterwards are not known. Only very recently have any data been collected which prove the carriage or spores by wind over any large area or to any great distance. It has been noticed for some time, however, that diseases seem to spread in the direction of prevailing winds. McAlpine, as long ago as 1906, quoted Halsted's observations on the spread of Asparagus Rust. A field which had been cut to allow the new growth to escape *Puccinia Asparagi* was found to be infected five weeks later. Curiously enough, however, only one side of each plant was affected, and this side consistently faced towards an old and badly infected field of Asparagus. Also the crop standing behind an old house was almost free of infection. The wind had blown in a direction from the old infected field towards the new crop and over the house, and the latter had prevented the spores of the fungus from reaching the crop just behind it.

Woolman and Humphrey showed the relation of wind to the spread of Bunt in a similar way, in the Pacific North-West (U.S.A.). Carsner also gives details of the spread of *Bacterium lacrymans* on cucumber, and Atanasoff of *Gibberella Saubinetii* on rye.

Spores have been caught at various heights by "vaselined" slide traps exposed from aeroplanes. Stakman *et al.* were the first to exploit this method, and they found many kinds of spores even up to a height of 10,500 feet. In England, Dillon Weston has followed this lead. He found, as would be expected, that the nearer the surface of the ground the greater was the number of spores caught. At 9-10,000 feet bacteria only were caught. In summer much greater numbers of fungus spores and bacteria were caught than in the winter months. Some evidence was also obtained that clouds are more heavily charged with spores and bacteria than the air just below them.

The distance to which the spores of fungi can be carried is very important, especially in connection with the epidemiology of plant diseases. Stakman *et al.* found that the number of spores diminished the further they were caught from the centre of infection. Heald *et al.* proved that the spores of *Endothia parasitica* could be carried in large numbers to a distance of three to four hundred feet from their point of liberation, and considered that they might be carried much further. Snell reports a case in which Ribes bushes became infected by the aecidiospores of *Cronartium ribicola* from a source which was one and a quarter miles away, and in

which the carriage of the spores could have occurred only by wind. Butler discussed the relation of wind to spore dispersal and considered that the power of the wind to carry spores for very considerable distances has usually been exaggerated. He states that Bunt spores were not found at a distance of 250 yards from heavily infected fields in Russia and in Germany, although these spores fell copiously at a distance of 440 yards from an infected crop at Pullman, U.S.A. He also quotes the case of *Coleosporium euphrasiae*, the spores of which travelled in the air across water for a distance of five to eighteen miles and caused the infection of plants on islands.

Organised work has recently been carried out in Canada to ascertain the line of distribution of Black Stem Rust (*Puccinia graminis*). In Manitoba and Saskatchewan this rust was epidemic in certain years, of which 1927 was one. In Alberta the Rust was not so severe in that year. By careful distribution of spore-traps in the areas concerned, however, the amount and the dates of arrival of the Rust spores were discovered. The first infections occurred at Winnipeg and Morden, in Manitoba on July 6th, and subsequently Rust became general, as far north as Winnipeg and throughout south-eastern Saskatchewan, by July 18th. Afterwards it was traced in an epidemic course further north and westwards. In Alberta, epidemic infection did not occur, because of the greater distance the spores had to travel and because the prevailing winds were not east or south-east. Since conditions in Canada are not suitable for the over-wintering of the fungus, and since the possibility of infection from Barberry is stated to be negligible, it is concluded that primary infection arose from uredospores carried by winds coming from a region of infected fields in the United States south of Manitoba and eastern Saskatchewan, situated in the Dakotas and Minnesota. The data obtained with the aid of spore-traps in aeroplanes were instrumental in establishing the fact that rainy weather effectively clears the air of Rust spores, since few were caught in wet weather. In any case, observations which are being continued each year in Canada tend to prove that the wind is responsible for introducing Rust spores from the United States, as was maintained some years ago by Miss Newton.

Mehta has made observations, but of a general type only, on the appearance of Yellow Rust in the plains of India. The survival of this Rust occurs every year in the hilly districts, for example, at Muktesar, because of the cooler weather, and is accomplished on self-sown plants. Infection of the crop in January easily takes place. The spores of the Rust are believed to be carried by wind to the crops in the plains, a matter of a few miles only (the circuitous hill-paths from Muktesar to the plains are 28 and 24 miles). But the wheat-crop is not up before mid-November and the weather is then too cold in the hills to allow the fungus to sporulate. By January, the weather is warmer, and spores are formed, which are carried to the plains. In no other way can the infection of the crops in the plains be explained.

McCubbin attempted to calculate the distance to which spores of *Cronartium ribicola* could be carried by wind. He found that the most slowly falling spores took from four to five minutes to descend eight feet. By calculation, he determined that a thirty-mile wind would carry spores, starting at a height of eight feet, two and a half miles before they reached soil level, and that they would travel ten miles if liberated from a "hill" thirty-two feet in height. Weston calculated that the spores of *Sclerospora philippinensis*, falling nearly twelve feet in six seconds, would be carried only eighty-eight yards by a thirty-mile wind, before reaching the soil level. In nature it has abundantly been demonstrated that spores may reach a height of ten thousand feet and more. At such heights, spores should be carried hundreds of miles by moderate or strong winds. Whether

they are able to infect plants after travelling at such heights and under all conditions of weather, is not known at present, although Stakman states that altitude had no influence on the viability of the spores recovered at great heights. He had, however, no means of knowing for what period the spores had been in the air or of estimating the influence of the duration of this period on the spores themselves.

GENERAL REVIEW

In the foregoing sections, it has been shown for some of the more important diseases of crop plants that each meteorological factor may have a more or less specific influence on the incidence and intensity of such diseases. In regard to some of them, it is true, there are conflcting observations, and to arrive at a definite conclusion as to the phenological relations of the diseases is as yet impossible. For others, however, the data seem to be sufficiently corroborative as to permit the conclusion that phenological correlation is possible.

For some diseases it is possible to state that when atmospheric and soil temperature and moisture conditions fall within certain limits, then disease is certain to occur, assuming, of course, the presence of the parasite. At present, it is not possible to forecast the intensity and duration of epidemics, even though it may-be possible to forecast that they will occur.

During the last few years, several countries have organised systems of forecasting the incidence of certain plant diseases, with the object of warning growers when to begin direct combative measures. France has started the practice of warning growers by informing them when the meteorological conditions indicate a possible outbreak of certain diseases and pests of the vine. At Montpellier, observations are received from fifty-nine outposts in the surrounding region, and also from other parts of France and abroad. By combining these with observations on crops at the station, advice is sent daily to subscribers as to the advisability of preventive treatment. This scheme has been in operation since 1923, and there are indications that the work is successfully fulfilling its objects.

A similar system has been in vogue in Italy since 1921, with the main object of forecasting attacks of Downy Mildew (*Plasmopara viticola*) on vines. Observe s are scattered over the three provinces of Turin, Cuneo and Novara, and their reports are sent to the Central Phytopathological Station at Turin. Advice is issued immediately meteorological conditions indicate that germination of the winter spores of the fungus and infection of the vines are probable.

In Germany, a centre wa established some time ago, where reports of meteorological conditions and of crop diseases could be received. There the data are sorted and examined to find correlations between the diseases and the weather. The United States Weather Bureau also carries out phenological and plant pathological observations; and, for a few diseases, such as Potato Blight and Apple Scab, close correlations have been obtained. Recently, both in America and Canada, reports have been issued relative to the first expulsion of ascospores from the perithecia of the Apple Scab fungus, and advice given as to the advisability of spraying. In Holland, too, attempts have been made to forecast the incidence of Potato Blight. During 1926 and 1927, the Dutch Phytopathological Service organised reports on weather and Potato Blight, the results of which confirmed van Everdingen's conclusions that it was possible to correlate outbreaks of this disease with certain weather conditions. As a result, the Royal Dutch Meteorological Institute at Te Bilt is carrying out observations and issuing warnings whenever conditions are such as to justify

the expectation of an impending outbreak of Blight. Although Miss Löhnis collected considerable data on the subject she did not succeed in establishing the existence of sufficient correlation to warrant the attempt to forecast epidemics. Van Everdingen, however, selected four conditions as enabling the onset of Potato Blight to be foretold :—(1) a night temperature below the dew point for four hours at least; (2) a temperature not falling below 10° C., (3) a mean cloudiness on the following day of not less than 0·8; and (4) rainfall during the following twenty-four hours of at least 0·1 mm. These are the data upon which the Dutch forecasts of outbreaks of Potato Blight are at present based.

When "combined weather" effects on diseases are studied, it is seen that, however well each of the separate factorial relations is understood, the combined result is not known. Usually the only conclusions that can be arrived at are confined to statements such as that a disease is favoured by one of four possibilities :— hot and wet, hot and dry, cold and wet, and cold and dry. These also register variations from mean local weather, and, naturally all the means will be different. Subjective human error is too strong to permit of success along such lines. Tehon was the first to apply more scientfic methods of correlating disease with phenology, and employed charts termed "hythergraphs." These are charts in which meteorological factors are measured in combination. Thus, the vertical scale represents temperatures and the horizontal scale rainfall. Tehon used Martin's data concerning Potato Blight, and, in replotting the combinations of temperature and rainfall, obtained a series of points which, when joined, formed curves that were circular, ovoid or elliptical, the curves being called "isopracts."In this way areas of various sizes were obtained which represented severe, mild, and no attacks of Potato Blight. By plotting temperature-rainfall data, and obtaining curves named "thermohyets," which represented the distribution-climate for certain diseases, he obtained areas outside of which the thermohyets did not correspond with the incidence of the diseases. Again, hythergraphs representing monthly or yearly disease-relatons were obtained. An even more important feature was indicated by this method, namely, the relation of thermohyets to intensity of attack. Tehon plotted figures obtained over a series of years, each having a different mean index of Rust infection, along with the corresponding mean annual thermohyet. The point so plotted lay in two lines, called "trend lines." The points on each of these were plotted on the other by means of compasses, as well as on the line mid-way between and parallel to the trend lines; and this line was called the line of true correlation. When the points corresponding to each index of infection were joined, curves were obtained which indicated the thermohyets of each index. In other words, by plotting a point in the graph indicating a forecasted thermohyetic, that point will lie between two fixed contour lines representing degrees of infection. Not only should it be possible by this method to forecast an epidemic outbreak but also the severity of infection. In order to do this, however, a standard must be fixed by which degrees of infection and of destructiveness can be measured. By the present method of personal estimation, scarcely any two observers would assign the same degree of infection for the same attacked plant.

Passing on to the problem of the provision of data, it must be evident that there is an enormous lack of detailed meteorological observations, possession of which would help to clear up many points. Up to the present the unit observation covers a large area, and consists, almost in every case, of temperature three times a day and not at night (a very important time), rainfall, sunlight and humidity in the open air. Data which would be more useful are those concerning conditions existing in the crop, and

only a few isolated workers have recorded such. Each factor in the crop will vary according to the type of crop plant. Roussakov examined many of these points. He found that there were considerable differences between open-air temperatures and those of the air within the crop. The temperatures in the crop also varied according to the time of day or night, and the presence of clouds and rainfall. For example, the open air temperature in the daytime was lower than that in the midst of the crop by 1°-3° C., but was higher at 9 p.m. by 4° 6·5° C., while the two nearly coincided at 7 a.m. The highest temperature of all at 9 p.m. was at the surface level of bare land, and the lowest temperature at the same time was at a height of 90 c.m. in the crop. The humidity varied greatly also, this being influenced by winds and by clouds. In a dry summer, the relative humidity was 85 per cent. near soil level, 72·5 per cent. at mid-crop height, and 67 per cent. at the top of the plants. In a wet summer, the relative humidity was more evenly distributed, that at the base of the crop being only 10 per cent. greater than that at the top. Since shading affects the temperature of the plants, as already explained in the section on light relations, and since humidity also does so, Roussakov's data relative to the penetration of sunlight into a crop are interesting. A crop of rye, with a fairly dense stand and from 150-160 cm. high allowed the following proportions of sunlight to penerate.

60-65 per cent.	sunlight penetrated down to	80-90 cm.	from oil level.
18-20 per cent.	,, ,,	25-30 cm.	,, ,,
10 per cent.	,, ,,	10-17 cm.	,, ,,
5 per cent.	,, ,,	5 cm.	,, ,,

Again, the details of distribution of spores by wind are imperfectly known. Little is known of the relative effects of the upper and lower air strata on spore viability, or concerning the possible length of suspension of spores in the air. For a few types of spores only has any relation of density to rate of fall been established in connection with the rate of deposit in winds of varying velocity.

CONCLUSION

There are many questions that the plant pathologist might be expected to answer, and the first is whether he is sure that certain groups of meteorological factors do lead to epidemic outbreaks of a disease or group of diseases.

In view of what has been said above, there can be no doubt but that meteorological factors do determine to a great extent outbreaks and epidemics of most plant diseases.

The group of factors primarily concerned consists in most cases of temperature, moisture (and humidity), light and wind, the combination varying according to the disease.

A second question is whether there are certain very specific meteorological factors upon which a particular disease (or group of diseases) appears to depend. This can also be answered with certainty. Controlled research in the laboratory has demonstrated that each disease has a very definite range within each of the meteorological factors. In nature, however, the greater and more irregular variability of these factors makes correlation in the field very difficult. Further work and far more data are required before the ranges that prevail in the field can be estimated.

Following this, he may be asked, thirdly, to indicate with one particular disease, or with a few, what the exact factors and their duration are, and what particular coincidence of these factors is necessary for the occurrence of an epidemic.

Fortunately, it is possible to give a definite example. The Potato Blight, caused by *Phytophthora infestans*, depends upon a set of conditions which are very specific. These have already been laid down by van Everdingen, and are the result of much research and of years of work. They have been mentioned previously, but may be repeated here. For the outbreak of this disease there are necessary :—(1) a night temperature, of four hours' duration at least, below dew point; (2) a temperature of not less than 10° C; (3) a mean cloudiness on the following day not falling below 0·8; and (4) rainfall of at least 0·1 mm. during the following twenty-four hours.

Fourthly, the plant pathologist may be asked what are the data that are needed to determine accurately the phenology of plant diseases and what are the methods suggested for obtaining them ?

For each important crop plant during the whole period of its growth and maturation the following meteorological data are required :—

(1) Air temperatures : (*a*) above the crop; (*b*) at the level of the top of the crop; (*c*) at mid-crop height; (*d*) at the base of the plants, and (*e*) in the soil. The temperatures should be recorded every two or three hours during the whole twenty-four hour period, or better still by a continuous method.

(2) The moisture content of the land : (*a*) bare, near the crop, and (*b*) under the crop; the usual precipitation records, measured twice daily and nightly.

(3) The relative humidity of the air : (*a*) above the crop; (*b*) at the level of the top of the crop; (*c*) at each quarter of its height within the crop, and (*d*) at the base of the crop. That just over bare land is also required. The records should be taken every three hours, day and night or preferably continuously.

(4) Cloud records and sunlight intensity; also relative penetrations of sunlight, clear and shaded, into the crop plants, for each degree of density and height of the plants in the crop.

(5) The relative penetration of precipitation into a crop, at each degree of density, and the length of time moisture remains on the foliage.

(6) The relative amounts of dew deposition in crops, at different heights in the crop, and for each state of temperature, moisture, and humidity as well as of crop density.

(7) The relative penetration of wind of varying degrees of force into the crop and its relation to crop humidity, temperature, and spore dispersal.

(8) The humidity and temperature of the higher air strata (100-15,000 ft.).

(9) More information relative to air currents and spore dispersal.

The methods to be employed for securing the data required cannot be left in better hands than those of the meteorologist himself. What is essential is a system of recording these data for each important crop plant in as many districts, climates and countries as possible. The British Empire offers plenty of scope as far as differences of climate are concerned.

If such a vast and varied array of meteorological data becomes available, the question will arise as to whose province it will be to correlate them with plant disease phenomena. If such correlation is to be done at all it is clear that the plant pathologist will have to stir himself and work out standardised methods by means of which "degrees of disease," or

"epidemic intensity" can be measured with accuracy, and without any disturbing factor due to the subjectivity of the recorder. These standardised methods will perhaps differ for the diseases of different crops, and to devise them will be no easy task; nor will their application in practice be possible except by those possessing almost an infinity of patience and perseverance. Limits of available space preclude the discussion of this matter here, but it may be said that in connection with the breeding of resistant varieties, particularly in the United States of America, some progress has already been made in formulating standards by means of which degrees of Rust attack on certain cereals can be recorded, so that accurate comparisons can be made.

Having secured meteorological data and those of disease intensity, the problem of correlation will become acute. Will the meteorologist or the plant pathologist or either of them be competent to carry out such correlation ? Or, will the task require a specialist "superman" in the form of a statistician ? The answer to such questions may perhaps be deferred for the present, but it may be pointed out that Tehon has already shown that the problem is one involving deep analytical and higher mathematical treatment; and the humble present-day plant pathologist may well feel that such a task would be well beyond his powers. What searchings of heart, if any, the meteorologist might have in regard to the task it is not for a plant pathologist like the present writer to enquire.

The present paper has been an attempt to show that a relationship exists between plant pathology and meteorology, and to indicate some ways in which the study of that relationship might with profit be intensified. The theme has been based on, and illustrated exclusively by, existing plant pathological literature, but it is felt that in meteorological literature there may exist papers that would be of interest to plant pathologists in trying to solve their problems. If so, plant pathologists would be under a debt of gratitude to any meteorologist who would be good enough to bring such work to their notice.

The writer wishes to record his sincere thanks to both Dr. Butler and Dr. Pethybridge for their kind help and criticism, and to the former also for placing the use of the library of the Imperial Bureau of Mycology at his disposal.

MEETINGS, CONFERENCES, ETC.

MINUTES OF THE EIGHTH ORDINARY GENERAL MEETING OF THE RUBBER RESEARCH SCHEME (CEYLON)

THE eighth Ordinary General Meeting of the Rubber Research Scheme (Ceylon) was held in the old Legislative Council Chamber, Colombo, at 11 a.m. on the 25th of April, 1930.

Dr. W. Youngman, Director of Agriculture and Chairman of the Executive Committee of the Scheme, occupied the chair.

1. REPORT OF THE EXECUTIVE COMMITTEE

Moving the adoption of the reports, accounts and balance sheet for 1929, Dr. Youngman said:

It is my pleasure to present to you the eighth annual report of the Executive Committee of the Rubber Research Scheme (Ceylon) for the year ending December 31, 1929. The membership of the Scheme, as you will see in the report, has diminished by six, there having been a loss of 9 subscribers and an accession of 3. Whilst we should like to see the membership increase rather than diminish, it is significant that the subscriptions have increased due to an expansion in the yield of rubber.

The accounts and balance sheet for the year are submitted along with the report, and we shall ask you to pass them, they having been duly certified by your auditors.

You will observe that this is the first year in which our expenditure has exceeded the income, the result of the growth of the Scheme, for our revenue has not diminished. This state of affairs is bound to be until we can get the Scheme put on a more permanent basis by the passing of the Rubber Research Scheme Ordinance. The draft Ordinance is still under consideration by a Select Committee of the Legislative Council.

Although the Scheme seems to be working as well as could be expected under present arrangements, pending its establishment on a permanent basis by the passing of an Ordinance, the appointment of a Director seems much to be desired.

Many of the functions of a Director were discharged by your Organising Secretary, Mr. Mitchell, who left at the end of September, 1929, after having discharged these duties for eight and half years. I am sure you will acquiesce in the appreciation of his work recorded by your Executive Committee. For the time being, your Chemist, Mr. T. E. H. O'Brien, is acting as Chief Technical Officer, co-ordinating the scientific staff generally and conducting the technical correspondence of the Scheme.

You will note that much attention has been given by your Technical Committee to the subjects of budgrafting and selection and that they formed a small Sub-Committee to deal with these important points.

Speaking personally as one with a slight acquaintance with the botany of crop plants, I feel sure that this is a very wise step and one from which much help to the industry can be hoped for. I have had occasion myself recently to devote attention to what is known as the vegetative reproduction of plants, that is the increase of plants by methods other than from seed,

and I have been astonished at the great gaps that exist in our knowledge of this important subject amongst plants generally. Of precise, exact knowledge of the influence of stock upon scion and of bud variation we have but little. We are at the present time at Peradeniya faced with a similar problem with regard to oranges and grapefruit. Although there is a far cry from these fruit trees to rubber yet the problem is the same and their example may serve to focus in your minds what it is. On the same orange tree there can at times be found two or more branches differing from one another considerably in certain visible characters such as the shape and form of their leaf and perhaps of their fruit. Budwood thus taken from such a tree would certainly propagate two or more kinds of tree. Now these characters are an outward and visible sign but we are perfectly justified in holding that there are other characters in plants that may not be outward and visible but that differ from branch to branch. Such a character would seem to be the latex secreting capacity of buds (which are incipient branches) in the rubber tree. Thus we are faced with the fact that until it is proved to be the case we are not justified in assuming that all the buds capable of producing new rubber trees will transmit the high or low latex yielding character of their parent. This problem presents many interesting side lines capable of being of great economic importance that require and will repay fuller investigation. One of the first things to be done is to obtain records of parent trees and then to see how and to what extent they transmit their characters to their buds. Work along these lines is in hand.

Of considerable interest in the report is Mr. Mitchell's account of the general condition of Ceylon rubber estates in which he summarises the chief diseases found of root, stem and leaf of the rubber tree and discusses some of the problems of rubber growing in general.

Your Chemist gives some account of his work on the curing of sheet rubber, comparing the effect of drying in hot air with and without smoke, also on the effect of iron in the water used for diluting latex upon the crepe, as well as other work on mould prevention, fractional coagulation and latex adulteration.

The Physiological Botanist describes much work of a field nature that had to be undertaken in connection with the Nivitigalkele Experiment Station and has published notes on Brown Bast, the Re-planting of old rubber and Budding of rubber and its meaning for Ceylon, amongst other things.

The Mycologist has devoted a great deal of attention to the *Oidium* leaf disease. In connection with this he has made some interesting experiments with Sulphur spraying as a preventative and he will show us some photographs today and tell us about them in connection with this work as I thought the Committee would like to see them. Other useful work on diseases of Bud Shoots, Bark Rot and other troubles is described.

I think you will agree with me that the report shows a year of progressive work and that we are only waiting for the Rubber Research Scheme Ordinance to help us to progress further still.

One other point should be mentioned and that is the coming departure from amongst us of Dr. Small who until recently acted as your Chairman. I am sure you will agree when I say that this Committee is indebted to him for the able and careful way in which he conducted its affairs during the period of his stewardship.

I have the pleasure to move the adoption of the report and accounts for the year 1929.

The motion was seconded by Mr. J. D. Hoare and was carried unanimously.

2. REPORTS OF THE TECHNICAL OFFICERS

The Chairman suggested in connection with the reports of the technical officers of the Scheme, that it would be suitable for Mr. Murray, the Mycologist, to present photographs and details of sulphur dusting carried out by him as a means of controlling Oidium. A dusting machine obtained from Java had been employed, but a British machine was expected and would be tried shortly. Mr. Murray read a preliminary report of his investigations on sulphur dusting as a means of controlling Oidium, which is printed separately at pages 347 to 349 and which has been issued as Leaflet No. 11 of the Rubber Research Scheme (Ceylon).

Mr. Collett moved a vote of thanks to Mr. Murray for his interesting report and enquired whether the Java sulphur was quite satisfactory. Mr. Murray replied that he had nothing to say against Java sulphur, but he was hoping to use American sulphur shortly in Uva. The American sulphur had the advantage of being specially prepared and does not need drying or sifting and is comparatively free from acid. The American sulphur costs roughly from 30 to 50 per cent. more than the Java sulphur. There was little difference between the two in the fineness of the powder. Replying to further questions from Mr. Wilmot A. Perera and Mr. O'Brien, Mr. Murray stated that the Dutch machine was manufactured in Java, and that it would be feasible to dust low-lying rubber from hillsides.

3. REPORT OF THE LONDON ADVISORY COMMITTEE

The report of the London Advisory Committee was accepted without comments.

4. AUDITORS

The Chairman proposed and Mr. Davidson seconded, that Messrs. Duncum, Watkins, Ford & Co. be re-appointed Auditors for 1930, on the same remuneration as for 1929, viz., Rs. 500. This was approved unanimously.

5. CONCLUSION

Mr. Collett then proposed a hearty vote of thanks to Dr. Youngman for his chairmanship and his able speech in proposing the adoption of the report. He took the opportunity to extend a cordial welcome to Dr. Youngman upon his assuming duties as Director of Agriculture and to second the appreciation expressed by him of the work of Dr. Small who had acted as Chairman for 15 months.

Dr. Youngman, returning thanks, said it gave him great pleasure to preside at these meetings and hoped the pleasure would be mutual for some time to come.

The meeting then concluded.

J. I. GNANAMUTTU,
Secretary,
Rubber Research Scheme,
(Ceylon).

Peradeniya,
May 10, 1930.

COCONUT RESEARCH SCHEME (CEYLON)

BOARD OF MANAGEMENT

MINUTES of the fifth meeting of the Board, held at 2.30 p.m. on Wednesday, April 2, 1930, in the old Legislative Council Chamber, Colombo.

Present: Dr. W. Youngman, (in the chair), the Hon. the Acting Colonial Treasurer, Mr. J. Fergusson, the Hon. Mr. A. Mahadeva, Mr. John A. Perera, J.P., U.P.M., Gate Mudaliyar A. E. Rajapakse, J.P., U.P.M., Mr. J. Sheridan-Patterson, J.P., U.P.M., and Mr. J. I. Gnanamuttu (Secretary).

Apology for absence was received from the Hon. Mr. C. H. Z. Fernando.

Chairman.—Before business commenced Mr. Mahadeva expressed the members' appreciation of the services of Dr. W. Small who had been Chairman from the date of inception of the Coconut Research Scheme and who had put in a considerable amount of work on its behalf. He proposed that a record of this appreciation should be made in the minutes. Mr. Sheridan-Patterson seconded, and the vote was carried unanimously.

Gate Mudaliyar A. E. Rajapakse welcomed Dr. Youngman to the Chairmanship of the Board, and was thanked by Dr. Youngman.

1. MINUTES

The minutes of the meeting held on January 20th, 1930, copies of which had been circulated to members, were taken as read and were confirmed and signed by the Chairman.

2. FINANCE

(a) The Chairman stated that the statement of receipts and disbursements of the Scheme during 1929, which had been circulated to members, was endorsed by the Colonial Auditor on March 4th, 1930, and published in the Government Gazette on March 7th, 1930. He added that the cost of audit of the accounts for 1929 would be under Rs. 100.

(b) The statement of receipts and expenditure for the quarter ended March 31st, 1930, was passed without comments. This showed a credit balance at that date of Rs. 86,833-94 of which Rs. 50,000 was on fixed deposit earning interest at 4% and Rs. 36,833-94 on current account.

(c) The Chairman reported that he had refunded to the Colonial Treasurer, subject to a recall on one week's notice, the sum of Rs. 250,000 received from him, of which Rs. 200,000 was the Government grant to the Scheme and Rs. 50,000 part of the loan provided under the Ordinance.

3. POWERS OF BOARD IN RELATION TO THE STAFF

In continuation of the discussion at the previous meeting, it was resolved that the Coconut Research Scheme should adopt the same procedure as the Tea Research Institute, namely that 5% of the officer's salary should be paid into a Provident Fund, the Scheme contributing a like percentage, to this being added such interest as can be earned.

Mr. Bickmore stated that the Provident Fund Ordinance which is under preparation would not apply to the subordinate staff. In reply to Mr. Mahadeva, he added that the objection was on the ground of the difficulty of working a large inclusive fund. He suggested that the Coconut Research Scheme would do well, in the same way as the Tea Research Institute, to go into the possibility of working a Provident Fund account with the Ceylon Savings Bank, the monthly abatements from the junior officers as well as the contribution by the Scheme being paid into such an account. This suggestion was adopted.

In regard to the senior staff, a provisional fund should be created pending the establishment of the permanent fund into which contributions to the credit of the senior officers would eventually be transferred. It was agreed that 4% interest on this provisional fund be paid by the Scheme, it being understood however that the maintenance of this rate cannot be guaranteed.

4. ESTATE SUB-COMMITTEE

(a) With reference to the correspondence with the lawyers of the Scheme, which had been circulated to the members, the Chairman read a further letter dated March 29th, 1930, from Messrs. F. J. & G. de Saram, and reported that although he had stipulated for the transference of the estate on May 1, delays were inevitable owing to the necessity of a clear verification of the title and the survey of the area to be taken over by the Scheme. It was resolved that the owner, Mr. Cosmas, should be informed through the lawyers that the acceptance of the estate would follow the receipt of a favourable report on the title deeds. In the meantime the survey should be proceeded with; in the event of the purchase not being completed, Mr. Cosmas would be reimbursed expenses incurred on the survey It was understood that upon the transfer of the estate the owner would hand over the entire May-June crop which was due to be picked by the middle of June. Mr. Fergusson stated that arrangements to convert the first crop into copra would be unnecessary as there was a ready market for the nuts.

It was decided that the Estate Sub-Committee should dissolve when the purchase of an estate has been completed.

(b) Mr. Furgusson suggested that another Sub-Committee should be appointed to go into the question of the bungalows, laboratory, etc., to be built on the estate. It was agreed that the question of buildings should await the acquisition of the estate and the arrival of the Director of the Scheme.

It was decided that the Chairman should give the necessary orders for the erection of permanent fencing on the purchased area of the estate when and if acquired. This fencing to be of barbed wire with iron or reinforced concrete posts.

5. STAFF

(a) *Appointment of Director of Research.*—After considerable discussion upon the applications received from the Selection Committee in London, Gate Mudaliyar Rajapakse proposed, and Mr. Fergusson seconded, that the post of Director of Research should be offered to Mr. W. E. de B. Diamond, Chemist in the Department of Agriculture, Nigeria. This was carried unanimously, and it was decided that the terms of the appointment should be the same as those mentioned in the advertisement of August 10, 1929, subject to the condition regarding contributions to a provident fund, which would be in terms of minute No. 3 above. It was desired that Mr. Diamond should come out as early as possible.

(b) *Appointment of Geneticist.*—The Chairman recommended that the filling of the other staff posts provided in the estimates should now be considered. After discussion, the Chairman was authorised to advertise in the five English daily newspapers of Ceylon and the Government Gazette for a Geneticist for breeding and selection work on the coconut palm and to cable to Mr. Stockdale in London with a view to his notifying interested Ceylon students in England. It was resolved that the post should be under agreement for a period of 4 years with option of renewal on the salary scale of £400 rising to £490 by annual increments of £30 convertible at present at Rs. 15 per £1 sterling. It was desired that the Chairman should interview three or four most likely candidates and make his recommendation to the Board.

(c) *Appointment of Technological Chemist.*—The post of Technological Chemist for work on the chemistry of the coconut and its commercial products was discussed. It was resolved that the appointment should be under agreement for a period of four years with option of renewal. Mr. Mahadeva, supported by Mr. Bickmore, was of opinion that annual increment of £40 should be offered. Mr. Fergusson proposed that the incremental rate must be increased to £50. This was seconded by Mr. Sheridan-Patterson and was carried by a majority of two votes. The scale adopted was: £600 rising to £750 by annual increments of £50. It was decided that the selection should be entrusted to the London Committee which had dealt with the post of Director of the Scheme, that Mr. Stockdale should be asked to advertise the post in the same way and that candidates already in the East be interviewed, if required, at Colombo. The Selection Committee to be asked to consider all applications and make a recommendation to the Board.

(d) *Formal sanctions.*—To meet audit requirements, formal sanction was recorded of the following payments made as from October 1, 1929, and provided for in the estimates for 1930.

Secretary.—Half cost of holiday travelling; railway warrants to be issued and actual cost debited to the Scheme.

Clerk/Shorthand-Typist.—Rent allowance calculated at 7½% of salary.

Office Peon.—Salary Rs. 240 per annum; rent allowance Rs 30 per annum.

By Order,
J. I. GNANAMUTTU,
Secretary,
Coconut Research Scheme,
(Ceylon.)

DEPARTMENTAL NOTES

PADDY COMPETITION, MATALE SOUTH, MAHA 1929-30

A paddy cultivation competition was held in Matale South for 1929-30 Maha season when 103 entries were received as against 293 last year. The smaller number was due to the failure of the monsoon. The competitors had cultivated their fields satisfactorily and had applied green and farmyard manure. The preliminary judging was carried out by the Agricultural Instructor. The final judging of the selected fields was done by the Divisional Agricultural Officer, Central Division. The 1st prize (of Rs. 30/-) was awarded to B. G. Kiri Banda of Colahenwatte, the second (of Rs. 20/-) to Aluwihare Ovillae Walauwa Tikiri Banda and the third prize (of Rs. 10/-) to T. B. Jayatilleke of Udagama. Departmental Certificates were also issued to the successful candidates.

PADDY CULTIVATION COMPETITION, MATALE EAST (MATALE PALLESIYA PATTU AND AMBANGANGA KORALE) MAHA 1929-30

A paddy cultivation competition was held in Matale East during 1929-30 when 113 entries were received, out of these 42 were disqualified as the plots were found to be less than an acre in extent. The competitors took considerable interest. The Agricultural Instructor visited the plots on several occasions and encouraged the cultivators to adopt better methods of cultivation, manuring, transplanting and weeding. The preliminary judging was carried out by the Agricultural Instructor. The selected fields were finally judged by the Senior Agricultural Instructor. The 1st prize of Rs. 30/- was awarded to E. M. P. Opalgolla of Ambana and the second prize of Rs. 20/- to S. T. Dingia of Kuruwewa.

The Ratemahatmaya, Matale East, took much interest and helped the Agricultural Instructor to make this competition a success. Departmental Certificates were also issued to the successful candidates.

PADDY SHEAF COMPETITION—YATINUWARA AND TUMPANE

A paddy sheaf competition was held in 1929-30 for Yatinuwara and Tumpane when there were 46 entries from Yatinuwara and 45 from Tumpane. The Agricultural Instructor visited the fields before harvest and the final judging of 100 sheaves of ear-heads was done by the Divisional Agricultural Officer, Central Division. The Tumpane competitors were very keen and showed great interest and their exhibits were of a high standard.

Two competitors tied for the third place.

The following were awarded prizes :

	Yatinuwara	*11 exhibits*	
1st prize	Katupullegedera Punchirala of Koladande	Rs.	25·00
2nd ,,	W. M. Mudiyanse of Menikdewela	,,	15·00
3rd ,,	H. M. Loku Banda of Ipeledena	,,	10·00
	Tumpane	*34 exhibits*	
1st prize	M. Piyadasa, Asst. Teacher, Hinigamuwa School	,,	25·00
2nd ,,	Mathuwa, Vidane Duraya of Colabawa.	,,	15·00
3rd ,,	M. B. Goonapala of Poholiadde	,,	10·00
	W. Kiriya of Paranagama	,,	10·00

ANIMAL DISEASE RETURN FOR THE MONTH ENDED 31st MAY, 1930

Province, &c.	Disease	No. of Cases up to Date since Jan. 1st 1930	Fresh Cases	Recoveries	Deaths	Balance Ill	No. Shot
Western	Rinderpest	480	62	75	322	17	66
	Foot-and-mouth disease	254	33	217	10	27	...
	Anthrax	...	...	...	...	...	...
	Piroplasmosis	...	...	...	...	...	...
	Rabies. (Dogs)	...	...	...	...	...	...
Colombo Municipality	Rinderpest	...	...	...	...	...	...
	Foot-and-mouth disease	441	11	422	12	6	1
	Anthrax	1	...	...	1	...	...
	Haemorrhagic septicaemia	5	2	...	5	...	...
	Black Quarter	2	...	...	2	...	...
	Rabies (Dogs)	7	...	...	...	...	7
	Bovine Tuberculosis	1	...	...	1	...	...
Cattle Quarantine Station	Rinderpest	...	...	...	...	...	...
	Foot-and-mouth disease	...	...	...	...	...	...
	Anthrax (Goats)	225*	30	...	225	...	...
Central	Rinderpest	...	...	...	...	...	...
	Foot-and-mouth disease	593	51	507	2	84	...
	Anthrax	1	...	...	1	...	...
	Piroplasmosis	4	...	1	3	...	...
	Rabies (Dogs)	2	1	...	1	...	1
Southern	Rinderpest	104	17	18	83	3	...
	Foot-and-mouth disease	259	...	253	6	...	...
	Anthrax	...	...	...	...	...	...
	Rabies (Dogs)	1	1	...	1	...	...
Northern	Rinderpest	...	...	...	...	...	...
	Foot-and-mouth disease	2975	305	2905	70	...	...
	Anthrax	...	...	...	...	...	...
	Black Quarter	126	77	...	126	...	...
	Rabies (Dogs)	3	3	...	...	...	3
Eastern	Rinderpest	...	...	...	...	...	...
	Foot-and-mouth disease	28	...	86	2	...	...
	Anthrax	...	...	...	...	...	...
North-Western	Rinderpest	3435	225	106	2522	27	780
	Foot-and-mouth disease	4	...	4	...	...	...
	Anthrax	...	...	...	...	...	...
	Pleuro-Pneumonia (in Goats) †	50	...	...	50	...	...
North-Central	Rinderpest	...	...	...	...	...	...
	Foot-and-mouth disease	1069	...	1045	24	...	...
	Anthrax	...	...	...	...	...	...
Uva	Rinderpest	...	...	...	...	...	...
	Foot-and-mouth disease	72	...	72	...	...	...
	Anthrax	...	...	...	...	...	...
Sabaragamuwa	Rinderpest	57	...	5	51	...	1
	Foot-and-mouth disease	1159	80	1075	10	74	...
	Anthrax	...	...	...	...	...	...
	Haemorrhagic septicaemia	9	1	...	9	...	...
	Rabies (Dogs)	9	2	...	2	...	7

* 1 case in a buffalo

† An outbreak which occurred in March.

G. V. S. Office,
Colombo, 13th June, 1930.

G. W. STURGESS,
Government Veterinary Surgeon.

METEOROLOGICAL REPORT

MAY, 1930

Station	Temperature				Humidity		Amount of Cloud	Rainfall		
	Mean Maximum	Difference from Average	Mean Minimum	Difference from Average	Day	Night (from Minimum)		Amount	No. of Rainy Days	Difference from Average
	°	°	°	°	%	%		Inches		Inches
Colombo	86·2	—0·8	77·1	+0·2	80	89	7·8	26·24	24	+12·59
Puttalam	86·0	—1·8	77·6	0	78	89	6·0	14·56	14	+11·11
Mannar	87·5	—3·0	79·0	—1·3	78	86	6·7	8·28	9	+ 6·27
Jaffna	86·4	—1·0	80·2	—1·2	81	87	4·9	10·59	5	+ 8·92
Trincomalee	89·7	—2·4	77·3	—0·8	69	84	4·3	17·10	8	+14·63
Batticaloa	89·7	—1·9	76·6	+1·5	72	88	6·0	7·42	4	+ 5·69
Hambantota	84·9	—1·9	76·0	—0·4	84	93	4·2	12·19	15	+ 9·02
Galle	84·1	—1·0	76·9	—1·2	84	88	6·9	18·45	26	+ 7·07
Ratnapura	87·7	0	74·0	—1·0	76	93	6·6	31·39	26	+13·19
A'pura	88·2	—2·4	75·8	—0·3	72	93	6·2	8·29	10	+ 4·94
Kurunegala	88·2	—1·4	75·3	—0·4	74	91	7·6	15·71	13	+ 9·18
Kandy	85·3	—0·3	70·2	—0·5	72	90	6·8	13·70	17	+ 8·01
Badulla	84·2	—1·2	65·5	0	68	92	5·5	8·99	9	+ 4·34
Diyatalawa	77·6	—0·4	59·5	—2·2	72	86	6·2	11·51	15	+ 6·35
Hakgala	72·5	—1·1	57·2	+0·3	78	86	5·4	17·21	17	+10·20
N'Eliya	69·2	—1·2	52·6	+0·2	80	91	7·2	18·32	17	+11·49

The chief meteorological factor in May was a depressional storm whose centre was first apparent off Hambantota on the morning of the 5th, and subsequently moved northward off the east coast and crossed the Indian cost south of Negapatam on the 7th. It gave heavy widespread rain on the 5th and 6th, particularly the former. I have not yet heard of a well-conditioned rain-gauge that failed to record at least an inch on that day.

Damage due to flooding was widespread, but most noteworthy in the Kelani Valley. Damage due to high wind was reported at Delft and other places in the extreme north. Considering that the records for low pressure were broken at Trincomalee and Jaffna, the surprising thing is not that this damage occurred, but that it was not more severe than was the case.

After the centre of the storm was over India it still gave heavy rain over western Ceylon on the 9th. On the 16th-20th there was but little rain, and from the 20th onward, though the number of wet days was about up to average, the quantity of rain was not excessive. However, any dificiency in the second half of the month was outweighed, and at all stations the month's total was above average.

The highest totals were Geekiyanakanda, 48·21, and Srikandura, 46·95 inches. Other stations with over 40 inches were Halwatura, Carney and Gendagala.

Palugaswewa recorded 12·73 inches on the 6th, and other falls of over 10 inches in a day were at Luccombe (Maskeliya), Kellie and Morootie, (Dolosbage), Yataderia (Undugoda), Blackwater (Nawalapitiya), Halwatura (Ingiriya), Trincomalee, Labugama and Talaimannar. Over three-hundred stations, or about 80%, reported at least 5 inches in a day.

Temperatures were on the whole below average. The maximum temperatures show this deficit rather more than the minimum ones do, which is the natural concomitant of the amounts of cloud and humidity having been above their averages.

The duration of sunshine was a trifle above average on the west and east coasts, but a little below average in the south.

Hail was observed at Diyatalawa on the afternoon of the 30th.

A. J. BAMFORD,
Superintendent, Observatory.